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Fort Leonard Wood German POW Stonework

Maintenance and Repair

Sarah Marie Jackson and Jason Church

July 2017



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Cover photo: Detail of German POW inscription on stonework located at Fort Leonard Wood (ERDC-CERL, 2016).

Fort Leonard Wood German POW Stonework

Maintenance and Repair

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Final report

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Prepared for U.S. Army Garrison Fort Leonard Wood
Directorate of Public Works
Environmental Division
Fort Leonard Wood, MO 65473

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Abstract

Federal preservation laws require federal agencies to identify, protect, and maintain their historic buildings and structures. The German POW Stonework Historic District, which is eligible for the National Register of Historic Places, recognizes and protects the stonework created by German prisoners of war (POWs) from 1942 through 1946. All structures, especially historic ones, require regular, planned, and appropriate maintenance and repair. After identifying issues with the condition of the historic stonework, architects at the U.S. Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC-CERL) requested technical assistance from the National Center for Preservation Technology and Training (NCPTT) on behalf of U.S. Army Garrison Fort Leonard Wood (FLW). Two experts from NCPTT made a site visit to inspect the stonework, taking samples and photos. Their technical report, made part of this ERDC-CERL contract report, provides recommendations for preservation or restoration of the stonework, following the *Secretary of Interior’s Standards for the Treatment of Historic Properties*. The NCPTT report also summarizes various threats to the condition of both stone and mortar. FLW’s Directorate of Public Works will use the report’s recommendations to correct existing issues and to maintain the historic stonework.

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Foreword

When assessing properties for architectural surveys at Fort Leonard Wood (FLW), Missouri, researchers from the U.S. Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC-CERL) noticed maintenance issues with stonework in FLW’s German POW Stonework Historic District. After discussion with FLW cultural resources personnel, ERDC-CERL contracted for technical assistance on the installation’s behalf from the National Center for Preservation Technology and Training (NCPTT) of the National Park Service.

The NCPTT provided its final report (TAR-2016-01), and that report is reproduced in its entirety as part of this contract report.

Adam Smith, M.Arch
Project Manager

Preface

This work was conducted by the National Center for Preservation Technology and Training under Interagency Agreement No. W81EWF60605855. Mr. Adam Smith (CEERD-CNC), Program Manager, monitored the work under Project 450959, funded by Military Interdepartmental Purchase Request (MIPR) 10660149. Ms. Stephanie L. Nutt was the technical monitor for U.S. Army Garrison Fort Leonard Wood.

The work was monitored by the Land and Heritage Branch (CEERD-CNC) of the Installations Division (CEERD-CN), at the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Dr. Michael Hargrave was Chief, CEERD-CNC; and Ms. Michelle Hansen was Chief, CEERD-CN. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. David W. Pittman.

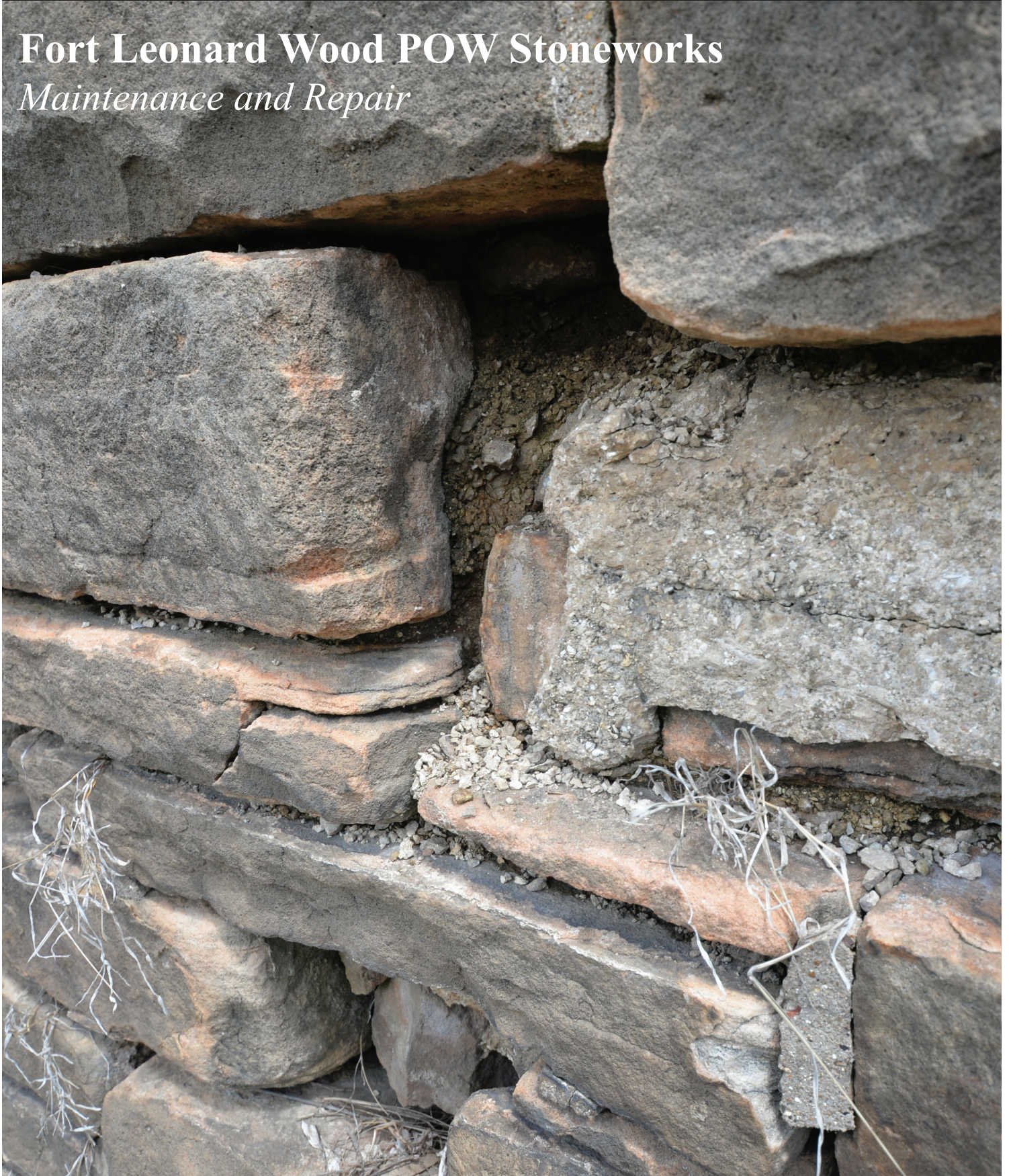
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Fort Leonard Wood POW Stoneworks

Maintenance and Repair



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Fort Leonard Wood German POW Stonework

Maintenance and Repair

Technical Assistance Report Series

TAR-2016-01

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Contents

Introduction	1
History	1
Site Visit	1
Recommendations	3
Threats to Stone	4
Historic Mortars	5
Mortar Analysis	5
Components of Mortar	5
Repointing Failing Mortar	6
Mixing Mortar	7
Filling the Joint	7
Cleaning Historic Resources	7
Landscape Maintenance	8
Conclusion	9
Treatment	10
Recommendations	
Fire Baptized Cemetery	11
Old Post Head Quarters	13
Post Cemetery	15
Rockwell Cemetery	17
Building 2101, Black Officers Club - Chimney	19
Building 2101, Black Officers Club - Retaining Wall	21
Garlington House	23
Constitution Avenue Bridge	25
Veterans Park	27
Mortar Analysis	
Sample 2101, Outside Chimney Pointing Mortar	30

Sample Fire Baptized Cemetery, Interior Wall Tooled Mortar	33
Sample Constitution Ave Bridge, Bedding Mortar	36
Sample Constitution Ave Bridge, Pointing Mortar	39
Additional Resources	
Repointing Mortar Joints in Historic Masonry Buildings	43
Dangers of Abrasive Cleaning to Historic Buildings	57
Preparation of Lime and Cement-Amended Mortars	66
Masonry Cleaning: Removal of Atmospheric Soiling, Graffiti, Stains, and Biogrowth	74

Figures

Figure 1. Delamination on the exterior of the chimney at the Black Officers Club. The stone could be consolidated, patched, or replaced depending on the decision of the site manager. If nothing is done the stone will continue to deteriorate until it is a complete loss. Photo NCPTT Sarah Marie Jackson	2
Figure 2. Repairs to the exterior wall of Rockwell Cemetery. The mix, finish, and color do not match the historical mortar. Photo NCPTT Sarah Marie Jackson	3
Figure 3. Jason Church removes a mortar sample from the exterior wall of Fire Baptized Cemetery. Photo NCPTT Sarah Marie Jackson	4
Figure 4. Deteriorated mortar and plant growth on the Constitution Ave. bridge. Photo NCPTT Sarah Marie Jackson	6
Figure 5. Deteriorated mortar and plant growth on the patio of Garlington House. Photo NCPTT Sarah Marie Jackson	8
Figure 6. Areas of the walkways and landing at Veterans's park have been "repaired". These stones are to spread out leading to large mortar joints that are a different color and don't match the historic work.	9
Figure 7. Historic stonework walkway was lifted and relaid next to the area where utility work was being undertaken. Photos NCPTT Sarah Marie Jackson	9

Introduction

The National Center for Preservation Technology and Training (NCPTT) was contacted by Adam Smith of the Construction Engineering Research Laboratory (CERL) on behalf of Fort Leonard Wood to request technical assistance in the development of treatment recommendations for the POW stonework. The scope of the requested work included the mortar specifications, treatment, and maintenance recommendations.

NCPTT staff traveled to the site May 2-4, 2016 to assess current conditions and take samples. Stonework was inspected in several locations and mortar samples were taken along with photo documentation of present condition. Recommendations were tailored and prioritized based on the needed work.

The following report summarizes the findings of the materials analysis. Following the introductory information regarding the study methodology, the report discusses the findings of the research and then makes recommendations for appropriate restoration materials. All extracted aggregate from the masonry materials will be submitted to the client with a hard copy of the report.

Field work for this report was conducted by Sarah M. Jackson and Jason Church, Architectural Conservator and Materials Conservator, NCPTT. For the site visit NCPTT staff were joined Adam Smith, CERL, and Stephanie Nutt, Fort Leonard Wood.

History

Located in south central Missouri, Fort Leon-

ard Wood was created in 1941 to train engineers for WWII and became a permanent fort in 1956. From 1942 through 1946, FLW served as an “Enemy Alien Internment Camp” where German and Italian POWs were imprisoned. The POWs were engaged in a wide variety of jobs on the Fort and as agricultural laborers at surrounding farms.

Amongst the artifacts that remain from the internment camp are more than 493 stone features constructed by the German POWs. Because of FLW’s need for drainage structures, the large quantity of stone, and the available prisoner labor force including experienced stonemasons, the German POWs built drainage ditches, culverts, retaining walls, and dams, but also a boat landing, chimneys, walkways, steps, and roads.

Site Visit

On May 2-4, 2016 Sarah Jackson and Jason Church performed a site visit to inspect the POW Stonework. Samples and photos were taken at -

- Interior fireplace, exterior chimney, rear retaining wall at Black Officers’ Club (Building 2101)
- Exterior wall at Rockwell Historic Cemetery
- Walkways, chimney and exterior fireplace at Garlington House
- Exterior wall at Fire Baptized Historic Cemetery
- Kansas/Constitution Ave. Culvert
- PVW Culvert
- Walkways at Veterans Park
- Constitution Avenue Bridge
- Post Cemetery
- Old Post Headquarters

Secretary on Interiors Standards for the Treatment of Historic Properties

Preservation focuses on the maintenance and repair of existing historic materials and retention of a property's form as it has evolved over time.

Rehabilitation acknowledges the need to alter or add to a historic property to meet continuing or changing uses while retaining the property's historic character.

Restoration depicts a property at a particular period of time in its history, while removing evidence of other periods.

Reconstruction re-creates vanished or non-surviving portions of a property for interpretive purposes.

The Roubidoux Sandstone used for the stonework was available locally. We did visit the quarry located at the site, but were unable to locate the sandstone. Sandstone is a sedimentary stone that is known for its earth-toned colors. The rock is porous and performs best when the end grain is facing the weather. Face bedded stones often face greater deterioration as layers can detach and spall off through weathering or freeze/thaw cycles.

All work to preserve or restore the stonework should be done following the Secretary on Interiors Standards for the Treatment of Historic Properties. The standards provide guidance and set the minimum that should be done to preserve and protect cultural properties. The two treatments that would be most applicable to this site are preservation and restoration. Some of the stonework are structural such as the chimneys, culverts, and walls while many of the others are more connected with the landscape such as walkways or weirs.

The choice of treatment depends on a variety of factors, including the property's historical significance, physical condition, proposed use, and intended interpretation. Historic buildings are used as an example below. The decision making process would be similar for other property types.

Figure 1 Delamination on the exterior of the chimney at the Black Officers Club. The stone could be consolidated, patched, or replaced depending on the decision of the site manager. If nothing is done the stone will continue to deteriorate until it is a complete loss. Photo NCPTT | Sarah Marie Jackson





Figure 2. Repairs to the exterior wall of Rockwell Cemetery. The mix, finish, and color do not match the historical mortar. Photo NCPTT | Sarah Marie Jackson

Recommendations

When maintaining or repairing historic stonework all work should visually and materially match the historic as closely as possible. For areas such as uneven pathways that may create a tripping hazard it may be necessary to remove the mortar joints and remove the stones to allow for a new base material. It is important to document with photographs and drawings the stonework so as to match the historic appearance, material, and layout as closely as possible. As much of the original stone as possible should be reused to complete the project and retain the historic fabric.

When the replacement mortar color or aggregate is dissimilar this can create a glaringly obvious visual difference that even the most untrained eye will be able to discern. The width of the mortar lines can also have a visual impact.

Inexperienced contractors may not have the knowledge and skills to complete the project without detailed instructions and specifications outlining the expectations for the project. For quality assurance for projects it is not uncommon to request that contractors have a minimum of 5 years' experience and can provide examples of similar work they have completed. The image on the right is an example of a wall that was repaired after being hit by a car. The mortar does not match existing mortar near the damage. The aggregate for the mortar was not sized correctly. The contractor added small stones on top of the mortar in an attempt to match the historic mix. The material mix, size, and color so poorly match the historic material that it is visually jarring to even the most untrained eye.

The finished tooling also can differentiate between existing or historic and new mortar. The expectation must be that the new will match as

closed as possibly, but will not look exactly the same. It will not have the same exposure as the historic mortar and the exact same materials may not still be available.

Threats to stone

Deferred maintenance or repairs can lead to additional damage or total failure of the resource. Annual or semi-annual inspection is recommended to monitor and determine any maintenance or repair needs. Greater deterioration or permanent damage to the resource may occur if repairs and maintenance do not occur within a timely manner. By dealing with an issue as it occurs this will help to avoid a more complicated and often costlier repairs in the future

Salt damage can cause disintegration of a stone surface. The presence of salts within the stone, in the grounds surrounding the stone, in irrigation water, in some herbicides, and in some cleaners, can migrate through the stone's porous network and cause damage. Salts are dissolved and transported by water. They can re-crystallize and exert pressures in the pores that may exceed the strength of the stone. Thus, do not use cleaners that leave behind salts to clean stones.

Freeze thaw cycles can increase stone weathering. Water can enter into openings, cracks, and pores of stone. If freezing temperatures exist, the water can freeze and expand. With many freeze thaw cycles, water can damage stone. , Since most cleaning efforts require saturating the stone with water or liquids, do

Figure 3. Jason Church removes a mortar sample from the exterior wall of Fire Baptized Cemetery. Photo NCPTT | Sarah Marie Jackson



not clean stones during freezing temperatures or when a freeze is expected within 48 hours of the cleaning.

Improper cleaning can stain the surface or accelerate stone deterioration. Damage can be done through poor selection of cleaning methods. This would include use of power washing equipment too close to the stone, not rinsing after application of cleaner, and using products in a greater strength than the manufacturer recommends.

Historic Mortars

Mortar is meant to be a sacrificial material that can be replaced. It should be weaker than the stone or brick that it is holding in place. It should fail from weathering or time before the more expensive building materials.

With historic materials such as low-fired brick or soft stone the mortar helped draw moisture out and expanded and contracted with wetting and drying cycles. When mortar fails you should scrape the joint and repoint with a mix as close to the original as possible.

Mortar Analysis

Mortar samples can be tested using acid digestion or thin section petrography to determine the original mix as close as possible. Acid digestion is a procedure that breaks down a mortar sample to determine the amount of binder, fines, and sand. Thin section petrography uses polarized light with an optical microscope to inspect and assess thin section of samples that have been mounted on a slide with epoxy resin and ground smooth to a thickness of 30 microns. The polarized light from different angles reveals the optical properties of the different minerals.

Components of Mortar

Historically mortars included an aggregate (sand), binder (lime), and water. Sand gives the mortar its color and texture and should be free from impurities. Sand is small particles that are natural decomposition of rocks, shells or coral. For the building industry sand is used in mortar to increase volume of the mix and add strength. Beach or river sand has rounded edges from the natural break down due to the force of the water. Manufactured sand has sharp, angular edges from the manual process breaking down larger material. The gradation of sand in mortar should have a range of particle size from small to large. The lime then fills in the voids between the particles to bind the mix together.

Lime is created by burning or heating limestone to release carbon dioxide creating quicklime. Quicklime is a very caustic material that can burn if touched with bare skin. To make a safer, easier to work with material quicklime is slaked with water to create hydrated lime or lime putty. Hydrated lime is a dry powder that is created with a small amount of water. If hydrated lime is left exposed to the environment it can begin to carbonate from moisture in the air and it no longer usable. Lime putty has a greater amount of water added to create a material the consistency of cream cheese that has a smooth, creamy texture. Lime putty has an unlimited shelf life as long as it is covered and water and in a sealed container. It will also continue to break down into smaller and smaller particles over time.

Water should be clean and free from acids, alkalis, and organic materials. Water is added to the sand and lime to increase the workability of the mix. As the mortar cures releasing the water the lime will carbonate reverting back to a limestone like material with similar properties.



Figure 4. Deteriorated mortar and plant growth on the Constitution Ave. bridge. Photo NCPTT | Sarah Marie Jackson

Natural cement and Portland cement are modern binders that can be used in addition to lime. Natural cement is the product of burning limestone with higher magnesium or clay content. Portland cement was developed by burning natural cements with additional pozzolanic additives at different temperatures. Natural and Portland are ground into a powder after burning and increase hardness, durability, and ease of mortar setting. For historic low-fired bricks or porous stones lime mortar is softer, porous, allows for expansion, and contraction of masonry unit. Modern construction materials are stronger and less porous which allows for harder, more durable mortar mixes.

Repointing Failing Mortar

Mortar is meant to be a sacrificial material that

is replaced periodically with appropriate mix that matches the original as closely as possible in color, texture, strength and tooling. The preferred tools for removing failing lime mortar are hand chisels and mash hammers. Alternative tools that may be necessary such as small pneumatically-powered chisels, scaler (power chipper), and thin diamond-bladed grinders should be approved by architect or project manager. All work should be performed when temperatures are between 40 and 90 degrees F. No work should be performed when temperatures will be outside this range within 24-48 hours following.

All work should be completed by a mason who has ideally a minimum five year's experience repointing historic masonry. They should be knowledgeable of the Secretary of Interior's

Standards and demonstrate proficiency in the tools planned for the project. It is recommended that contractors provide test panels using the materials for the project to demonstrate their ability to match the mortar mix, visual characteristics, and finish of the historic work. Work areas should have barriers for visitor protection. Adjacent materials and site should be protected during execution of work.

Repointing can be done as needed in specified sections or complete facades of buildings and will be determined on a case by case basis. Once the area for repointing is determined the mortar joints should be raked to a minimum depth of twice the height joint. If deteriorated mortar remains in the joint the depth raked can be increased, but not more than half the depth of the stone. If the mortar is deteriorated for more than half the depth of the stone reconstruction may be necessary.

If the mortar is soft or deteriorated raking the joints can be done with hand tools. For stronger mortars power tools may be necessary, but work should be done by someone experienced in this method to avoid damaging the stone. Using more powerful grinders on the stonework is not recommended when the joints are uneven or very thin. Mortar should be removed from joints to a uniform depth creating square corners. When this step is complete joints should be rinsed out to remove all dust and loose particles.

Mixing Mortar

When mixing the mortar the measurements should be done by volume with the dry ingredients mixed together before adding the wet. Half the water should be added to the mix before adding the remaining in small quantities until the correct consistency is obtained.

A drier mortar is easy to work with and will not shrink as much as one with excess water. Mortar should be used within 30 minutes of the final mixing. If the mortar becomes too dry to work with or a greater amount of time has passed a new batch should be mixed. An experienced mason will know how much mortar than will need to complete 30 minutes of work thereby decreasing waste.

When mixing new mortar for areas of unknown rations with historic 20th century stone work I would recommend a Type N Portland Cement at a 1:2 1/4 or 1:3 ration Cement to sand. Make sure to color match any existing mortar or to match what was there before removal. This will require a sand color match as well as choosing between a white and grey Portland Cement.

Filling the Joint

The failed mortar should be removed to a depth of 2 to 2 1/2 times the width of the joint. Once the failed mortar has been removed from the joint all debris should be removed by compressed air or a vacuum. A final step of rinsing the joints with a low pressure spray will remove any final debris and dust plus moisten the joint in preparation for tuck pointing. The joint is now ready to be filled with the recommended replacement mortar. This process called tuck pointing should be done with a pointing trowel from a mortar hawk or brick trowel. The mortar should be packed in as tight as possible leaving no gaps. The finished face of the joint should be tooled to match the original mason's intent.

Cleaning Historic Resources

While some biological growth is common over time it can become an issue if it is excessive, detracts from stonework, or needs to be removed for repairs. Biological growth and small

plants were observed to be growing on some of the stone. Soiling or plants indicate a higher level of moisture on the surface of the stone or the interior of the structure.

Once a plant has taken root the root system can work its way into the structure causing additional damage and draw moisture into the stonework. Moisture can be harmful during a freeze/thaw cycle as water expands and can lead to cracks or spalling. All cleaning of the masonry should be completed before the repointing begins. Any cleaning or work that requires wetting should be avoided when a freeze is expected within 24-48 hours.

Maintenance practices must have an eye toward the future. Many cleaning methods may be able to remove soiling from stone. Some will be more effective than others. But the long-term

effects must also be considered. Anyone developing a cleaning method must look at the soiling agent to be removed, the potential threats caused by the soiling, and the possible unintended results of cleaning.

Landscape Maintenance

Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures and trees with lawn care equipment, including:

- Creating a non-mow protective perimeter around features
- Attaching protective bumpers to the lawn mower

Figure 5. Deteriorated mortar and plant growth on the patio of Garlington House. Photo NCPTT



- Raising mower blades to avoid low-lying features, and
- Using smaller machines in small spaces

Using an herbicide to control weeds at the base of an historic feature will also create a protective perimeter between the feature and a lawn mower. While sometimes a good option, using herbicides can potentially damage built features.

Even with careful application, herbicide spray rarely is confined to the intended target. Spray on historic stone and masonry can cause long term damage to the material. Herbicides contain salts, and when absorbed into the stone, form crystals that expand. These crystals, called efflorescence, can appear as a powder or white line on the surface of historic materials. Pressure from the growing crystals can physically damage the historic stone.

- Herbicides applied directly to the ground can also be absorbed by brick and stone.
- Using herbicides can alter the appearance of a landscape. While it may be a time saving choice the result detracts from the landscape's historic character.

If you choose to use an herbicide, use the least amount necessary and apply with care. Do not apply on a windy day, as herbicide may hit unintended targets. Consider adding a temporary, water-soluble dye to the herbicide, which will help to show exactly what the spray hits unintentionally.

Figure 6. (Right Top) Areas of the walkways and landing at Veterans's park have been "repaired". Large mortar joints that are a different color and don't match the historic work. Photo NCPTT

Figure 7 (Right Bottom) Historic stonework walkway was lifted and relaid next to the area where utility work was being undertaken. Photo NCPTT

Conclusion

Portland Cement was first introduced into the United States in 1871. By the 1920's it was becoming the predominate mortar mixed in new construction in the United States. The stone work at Fort Leonard Wood was done in the 1940's by this time most mortar mixes in the United States with totally or predominantly comprised of Portland Cement.

The mortar(s) originally used on the stonework done by the POWs at Fort Leonard Wood was a more modern Portland based mortar. There is no visible evidence that it has not worked well with the cut and natural stone that was used throughout the base. Most of the failures visible in the work come from 70 plus years of natural weathering and wear on the features.



Treatment Recommendations

Fort Leonard Wood

Maintenance and Treatment Recommendations

Fire Baptized Cemetery

Description/Sample

Mortar sample was removed from the interior of the stone wall surrounded Fire Baptized Cemetery. There was visible hand tooling of the mortar. The joint was solid with little to no signs of deterioration. Overall the sample was a grey appearance with a majority of small quartz aggregates mixed with some large tumbled pieces of various red hues. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely Grey Portland.



This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The exterior wall shows no visual structural issues at this time, although in many areas the finish mortar is deteriorated or missing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire wall. The historic mortar that is in good condition needs no additional work. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

If the stone is loose and the mortar is deteriorated the stone may need to be removed, cleaned and re-laid. If there are repairs or not made and inspected periodically there is a chance the loose stones may fall or be taken from the site.



If there is plant growth this indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional moisture movement in the wall. Biological growth can be removed with biocidal cleaner such as D/2. This often occurs in shaded areas that take longer for the surface to dry. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part Grey Portland Cement

2 parts masonry sand with a similar gradation curve making sure to include the larger aggregate

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Old Post Head Quarters

Description/Sample

Mortar sample matched the same characteristics as the sample from the interior of the stone wall surrounding Fire Baptized Cemetery. The joints were solid with little to no signs of deterioration. Overall the sample has a grey appearance with a majority of small quartz aggregates mixed with some large tumbled pieces of various red hues. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely Grey Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The short wall and walkways show no visual structural issues at this time, although in areas the mortar is deteriorated or missing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire wall or walkway unless there is an issue with structural integrity or human safety. The historic mortar that is in good condition needs no additional work. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Biological growth and deteriorated mortar on walkways and stairs near Old Post Head Quarters.

If the stone is loose and the mortar is deteriorated the stone may need to be removed, cleaned and re-laid. If the repairs are delayed or the stonework is not inspected periodically there is a chance the loose stones may fall or be taken from the site.

Plant growth indicates deteriorated mortar allowing the roots to grow into the walkways and short walls. They should be removed and the mortar replaced to deter additional moisture

movement in the wall. Biological growth can be removed with biocidal cleaner such as D/2. This often occurs in shaded areas that take longer for the surface to dry. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part Grey Portland Cement

2 parts masonry sand with a similar gradation curve making sure to include the larger aggregate

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Post Cemetery

Description/Sample

Mortar sample matched the same characteristics as the sample from the interior of the stone wall surrounding Fire Baptized Cemetery. Overall the sample has a grey appearance with a majority of small quartz aggregates mixed with some large tumbled pieces of various red hues. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely Grey Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Recent repointing or repairs on the cemetery gate columns visually do not match historic mortar. The color and physical characteristics do not match historic mortar

Recommendations

The mortar joints where visible seem to be in good condition. There is extensive biological growth including lichens and moss. If there is plant growth this indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional moisture movement in the wall. While it is not likely for surface biological growth to damage the structural stability can lead to staining and does hold additional water on the surface.



Moss and lichens are visible on the side and top of the perimeter wall.

The moss may need to be wetted to loosen attachment to the wall. Using a plastic putty knife remove as much as possible without marking the stone. Using a biocidal cleaner and natural bristle brush apply and clean following the manufacturer's instructions. Biological growth often occurs in shaded areas that take longer for the surface to dry. This will eventually reoccur if the resource is shaded so creating a maintenance plan that includes annual inspections and a cleaning protocol may be helpful.

It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire wall unless there is an issue with structural integrity, human safety, or the resource is damaged. The historic mortar that is in good condition needs no additional work. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part Grey Portland Cement

2 parts masonry sand with a similar gradation curve making sure to include the larger aggregate

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Rockwell Cemetery

Description/Sample

Mortar sample matched the same characteristics as the sample from the interior of the stone wall surrounding Fire Baptized Cemetery. Overall the sample has a grey appearance with a majority of small quartz aggregates mixed with some large tumbled pieces of various red hues. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely Grey Portland.



Tooling marks visible on historic mortar.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The perimeter wall shows no visual structural issues at this time, although in areas the mortar is deteriorated or missing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire wall unless there is an issue with structural integrity or human safety. The historic mortar that is in good condition needs no additional work. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Stones have detached from the wall and need to be reattached with new mortar.

If the stone is loose and the mortar is deteriorated the stone may need to be removed, cleaned and re-laid. If the repairs are delayed or the stonework is not inspected periodically there is a chance the loose stones may fall or be taken from the site.

Plant growth indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional moisture movement in the wall. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part Grey Portland Cement

2 parts masonry sand with a similar gradation curve making sure to include the larger aggregate

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Building 2101, Black Officers Club - Chimney

Description/Sample

Sample 2101 was removed from the lower exterior part of the chimney of Building #2101. From the photograph it shows that this joint was solid with little to no signs of deterioration. Overall the sample was a white matrix with buff and red aggregates all fairly small. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was White Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The chimney shows no visual structural issues at this time, although in areas the mortar is deteriorated or missing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire wall unless there is an issue with structural integrity or human safety. The historic mortar that is in good condition needs no additional work.

No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Close up picture of the mortar joint on the exterior of the chimney at the Black Officer's club.

Plant growth indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional moisture movement in the wall. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It

can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part White Portland Cement

3 parts masonry sand with a similar gradation curve

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Building 2101, Black Officers Club – Retaining Walls

Description/Sample

NCPTT compared mortar samples from all the locations to determine which mortars had a similar mix. The retaining walls near the Black Officers Club has a mix similar to the bedding mortar samples removed from the stone culvert lining the canal on the corner of Kansas and Constitution Ave. Overall the sample had a buff appearance with a majority of small quartz aggregates mixed with some large sharp grey pieces. The large sharp pieces match what has been seen at the quarry at Fort Leonard Wood. The samples appeared to have more matrix than aggregate. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The retaining wall is in failure mode which is evident from the cracking and movement. The wall could be reinforced by tying it back into the ground with a wall anchor system or a helical tieback system. Either system would restore structural integrity. An engineer should be consulted on this issue to provide a structurally sound solution.

Bedding Mortar

Original mix was;

3 parts White Portland Cement

2 parts masonry sand with an irregular gradation curve, the larger sharp aggregate most likely came from the quarry at Fort Leonard Wood.

Replicating this mix will work but may not be recommended. The recommendation is to go with a more traditional mix with White Portland (1 part) and standard Masonry sand (3 parts).

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Pointing Mortar

The wall has been repointed in the recent past and no original mortar could be found.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Garlington House

Description/Sample

NCPTT compared mortar samples from all the locations to determine which mortars had a similar mix. The Garlington House patio has a mix similar to the samples removed from the stone culvert lining the canal on the corner of Kansas and Constitution Ave. Overall the sample had a buff appearance with a mix of red hued aggregates. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The patio shows deterioration of the mortar that has allowed plant growth between the stones. The vegetation needs to be removed and the mortar replaced. When you remove that amount of vegetation there is a possibility that the patio may need a new base material to bring up to current code and the stones relaid. If the stones are uneven or loose this will increase structural integrity and resolve any issues with human safety.



Grass growing between the stones of the patio indicate deteriorated mortar.

Plant growth indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional root growth between and under the stones. Biological growth can be removed with biocidal cleaner such as D/2. This often occurs in shaded areas that take longer for the surface to dry. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Mortar

1 part White Portland Cement

2 parts masonry sand with a similar gradation curve

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Constitution Avenue Bridge

Description/Sample

Bedding Mortar sample was removed from the stone culvert lining the canal on the corner of Kansas and Constitution Ave. From the photograph it shows that the bedding mortar is starting to deteriorate but still intact enough for analysis. Overall the sample had a buff appearance with a majority of small quartz aggregates mixed with some large sharp grey pieces. The large sharp pieces match what has been scene at the quarry on base. The samples appeared to have more matrix than aggregate. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The culvert/bridge has extensive mortar failure of the stonework we inspected. If repointing and repairs are not done soon this may need complete reconstruction in the future. For many repointing projects repointing only needs to be undertaken where the mortar is failing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire facade unless there is an issue with structural integrity or human safety.



The entire exterior of the culvert needs the mortar replaced. Failing mortar must first be raked from the joints. Care should be given so that the mortar is not removed more than half the depth of the stone. If mortar is failing at a greater depth consideration should be given to rebuilding the façade. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Fort Leonard Wood should develop a SOP for landscape maintenance on or near cultural resources. Mowing is one of the most time-consuming maintenance jobs at most historic sites. It can also be one of the most destructive practices if it is not done carefully. There are several ways to avoid contacting structures with lawn care equipment such as creating a non-mow protective perimeter around features, attaching protective bumpers to the lawn mower, raising mower blades to avoid low-lying features, and using smaller machines in small spaces.

Bedding Mortar (Constitution Bridge and channel)

Original mix was;

3 parts White Portland Cement

2 parts masonry sand with an irregular gradation curve, the larger sharp aggregate most likely came from the quarry at Fort Leonard Wood.

Replicating this mix will work but may not be recommended. The recommendation is to go with a more traditional mix with White Portland (1 part) and standard Masonry sand (3 parts).

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Pointing Mortar (Constitution Bridge and channel)

1 part White Portland Cement

2 parts masonry sand with a similar gradation curve

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Fort Leonard Wood

Maintenance and Treatment Recommendations

Veterans Park

Description/Sample

NCPTT compared mortar samples from all the locations to determine which mortars had a similar mix. Mortar samples were removed from the stone culvert lining the canal on the corner of Kansas and Constitution Ave. From the photograph it shows that the joints were washing out as the mortar begins to fail. Overall the sample had a buff appearance with a mix of red hued aggregates. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Recommendations

The walkways show no visual structural issues at this time, although in areas the mortar is deteriorated or missing. It is recommended that only the areas that are experiencing mortar failure need to be repointed and not the entire walkway unless there is an issue with structural integrity or human safety. The historic mortar that is in good condition needs no additional work. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



If the stone is loose and the mortar is deteriorated the stone may need to be removed, cleaned and re-laid. If the walkways are going to be deconstructed for utility or site work they should be documented before any work begins. Lifting the stones out of the way and relaying them in the same pattern will assist in reconstructing the walkways.

Plant growth indicates deteriorated mortar allowing the roots to grow into the wall. These should be removed and the mortar replaced to deter additional moisture movement in the wall.

Biological growth can be removed with biocidal cleaner such as D/2. This often occurs in shaded areas that take longer for the surface to dry. While it is not likely for surface biological growth to damage the structural stability some can lead to staining and does hold additional water on the surface.

Mortar

1 part White Portland Cement

2 parts masonry sand with a similar gradation curve

Water should be added at the mason's discretion to form a workable mortar for the weather and moisture conditions present.

Mortar Analysis



Sample 2101, Outside Chimney Pointing Mortar Mortar Analysis for Fort Leonard Wood Preliminary Report

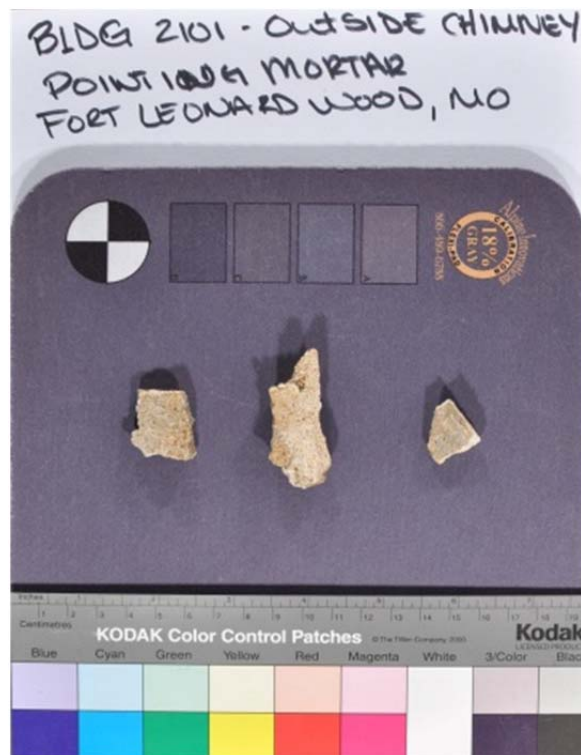
Report Date	August 2, 2016	Customer	Fort Leonard Wood
Company	National Center for Preservation Technology and Training	Site Address	Fort Leonard Wood MO, 65473
Address	645 University Parkway Natchitoches, LA 71457	Lab Technician	Jason Church

Introduction

In this document you will find the results of our laboratory testing on the mortar sample from Fort Leonard Wood Army Base. The samples were collected in the field by Jason Church in preparation of the preservation work that is planned for the on the masonry work done by German POWs during WWII.

This report is for Sample 2101 which was removed from the lower exterior part of the chimney of Building #2101 (See lower picture on page 2). From the photograph it shows that this joint was solid with little to no signs of deterioration.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Description

Sample 2101 was three separate pieces all $\frac{1}{4}$ " thick (size of the mortar joint). The largest piece was $1\frac{7}{8}$ " x $\frac{3}{4}$ ". Overall the sample was a white matrix with buff and red aggregates all fairly small. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was White Portland.

Munsell Color Chart (Soil)		
Mortar sample before acid digestion appeared to be a very soft buff color.		
Hue	Value	Chroma
10Yr	8	2

Analysis

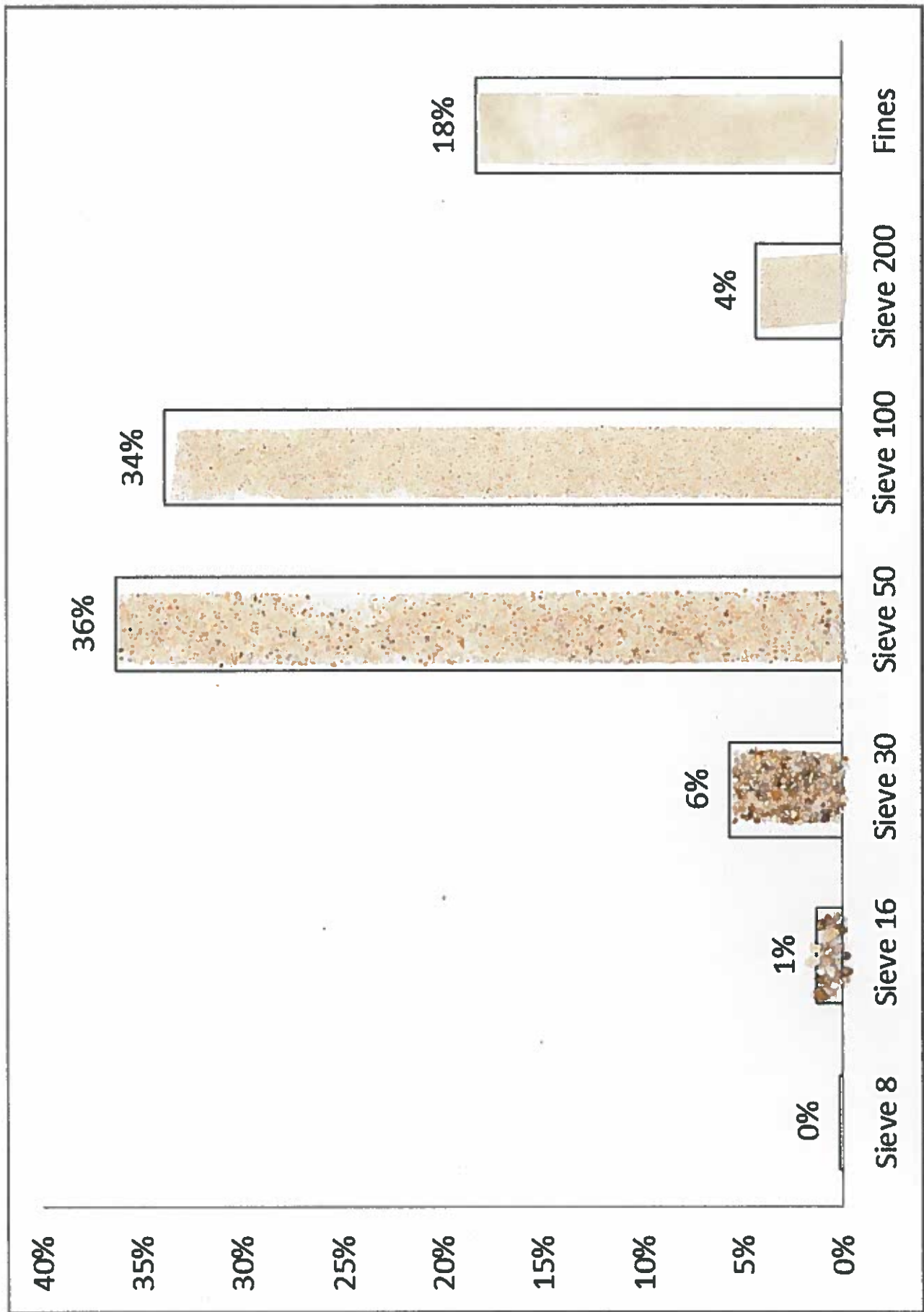
The mortar sample was crushed into a consistent size and weighed prior to dissolving the binder (calcium carbonates) from the sample using acid digestion. After diluting the acid, the remaining sample was filtered to separate the fines from the heavier aggregate. The two were then dried and weighed. The sieve method was used to separate the sand particles based on size. This is represented in the sand gradation chart. The best mortar mix produces a bell shaped gradation.



Mortar Analysis	
Original Weight of Sample	14.4652 g
Weight of sample after digestion	11.0588 g
Acid Soluble Material	3.4064 g
Leaves a Mix Ratio of	1:3

Sand Grain Distribution		
2.36 mm – No. 8	.0229 g	0 %
1.18 mm – No. 16	.1511 g	1 %
600 Micro – No. 30	.6282g	6 %
300 Micro – No. 50	4.0171 g	36 %
150 Micro - No. 100	3.7408 g	34 %
75 Micro – No. 200	.4741 g	4 %
Remaining Fines	2.0246g	18 %







Sample Fire Baptized Cemetery, Interior Wall Tooled Mortar Mortar Analysis for Fort Leonard Wood Preliminary Report

Report Date	August 2, 2016	Customer	Fort Leonard Wood
Company	National Center for Preservation Technology and Training	Site Address	Fort Leonard Wood MO, 65473
Address	645 University Parkway Natchitoches, LA 71457	Lab Technician	Jason Church

Introduction

In this document you will find the results of our laboratory testing on the mortar sample from Fort Leonard Wood Army Base. The samples were collected in the field by Jason Church in preparation of the preservation work that is planned for the on the masonry work done by German POWs during WWII.

This report is for Sample Fire Baptized Cemetery, Interior Wall Tooled Mortar which was removed from the stone wall surrounding the Fire Baptized Cemetery (See lower picture on page 2). From the photograph it shows that this joint was solid with little to no signs of deterioration.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Description

Sample Fire Baptized Cemetery, Interior Wall Tooled Mortar was seven separate pieces. The largest piece was 1 1/2" x 1" x 3/8". One side of the largest piece is uniformly pink, this is due to it bonding with the surrounding stone and removing the stone when the joint failed. Overall the sample was a grey appearance with a majority of small quartz aggregates mixed with some large tumbled pieces of various red hues. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely Grey Portland.

Munsell Color Chart (Soil)		
Mortar sample before acid digestion appeared to be a very grey color.		
Hue	Value	Chroma
5Yr	7	1

Analysis

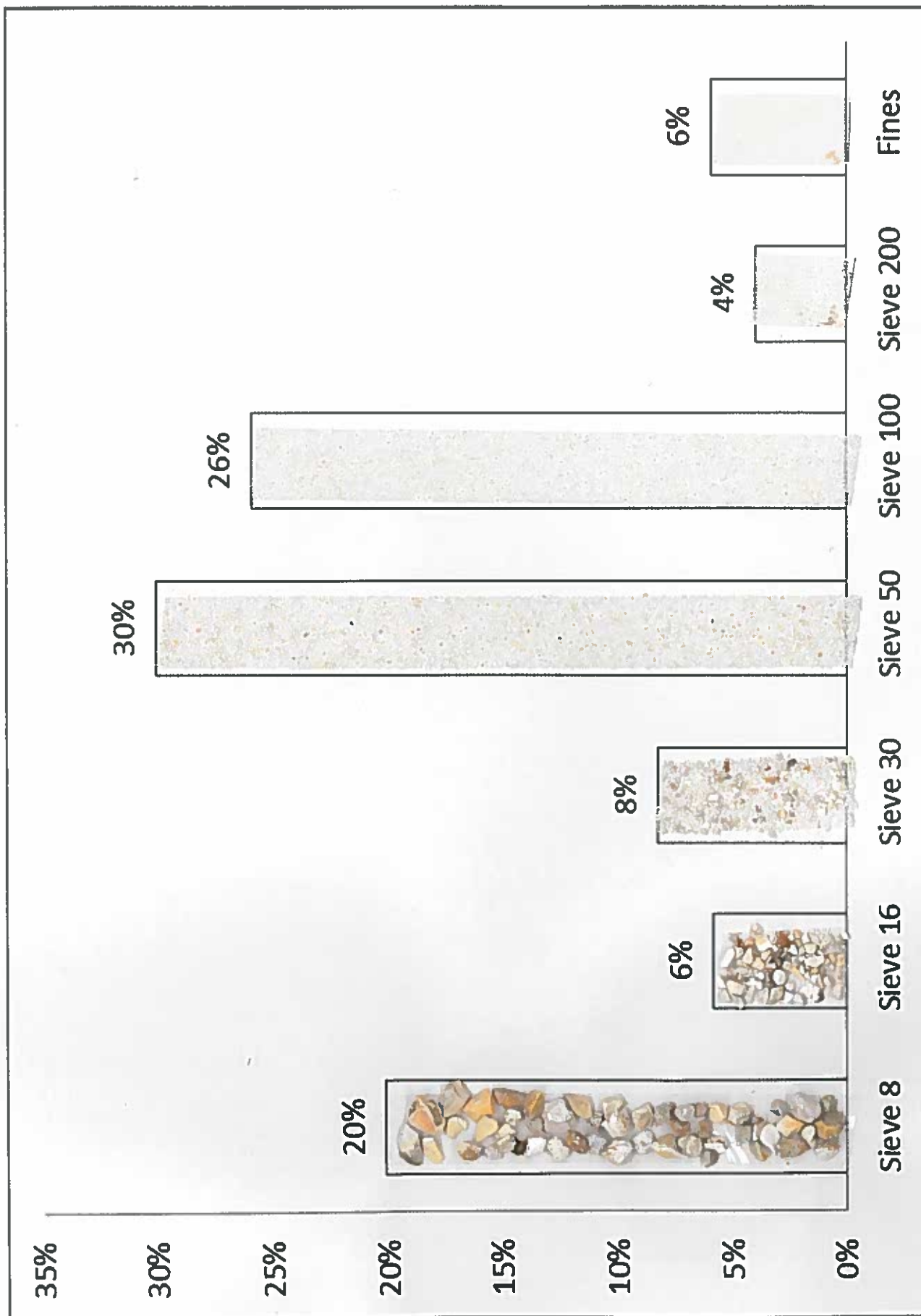
The mortar sample was crushed into a consistent size and weighed prior to dissolving the binder (calcium carbonates) from the sample using acid digestion. After diluting the acid, the remaining sample was filtered to separate the fines from the heavier aggregate. The two were then dried and weighed. The sieve method was used to separate the sand particles based on size. This is represented in the sand gradation chart. The best mortar mix produces a bell shaped gradation.



Mortar Analysis	
Original Weight of Sample	28.2347 g
Weight of sample after digestion	18.9064 g
Acid Soluble Material	9.3283 g
Leaves a Mix Ratio of	1:2

Sand Grain Distribution		
2.36 mm – No. 8	3.7997 g	20 %
1.18 mm – No. 16	1.1055 g	6 %
600 Micro – No. 30	1.5644 g	8 %
300 Micro – No. 50	5.6748 g	30 %
150 Micro - No. 100	4.8945 g	26 %
75 Micro – No. 200	.7475 g	4 %
Remaining Fines	1.12 g	6 %







Sample Constitution Ave Bridge Bedding Mortar Mortar Analysis for Fort Leonard Wood Preliminary Report

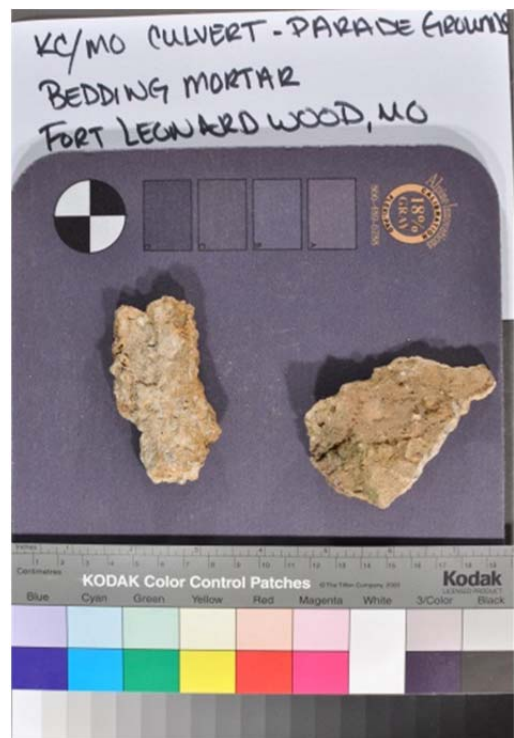
Report Date	August 2, 2016	Customer	Fort Leonard Wood
Company	National Center for Preservation Technology and Training	Site Address	Fort Leonard Wood MO, 65473
Address	645 University Parkway Natchitoches, LA 71457	Lab Technician	Jason Church

Introduction

In this document you will find the results of our laboratory testing on the mortar sample from Fort Leonard Wood Army Base. The samples were collected in the field by Jason Church in preparation of the preservation work that is planned for the on the masonry work done by German POWs during WWII.

This report is for Constitution Avenue Bridge at Parade Grounds, Bedding Mortar which was removed from the stone culvert lining the canal on the corner of Kansas and Missouri roads (See lower picture on page 2). From the photograph it shows that the bedding mortar is starting to deteriorate but still intact enough for analysis.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.



Description

Sample Constitution Avenue Bridge at Parade Grounds, Bedding Mortar was in two large separate pieces. The largest piece was 3" x 2"x 1/2". Overall the sample had a buff appearance with a majority of small quartz aggregates mixed with some large sharp grey pieces. The large sharp pieces match what has been scene at the quarry on base. The samples apperied to have more matrix than aggregate. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.

Munsell Color Chart (Soil)		
Mortar sample before acid digestion appeared to be a very buff color.		
Hue	Value	Chroma
2.5Yr	8	2

Analysis

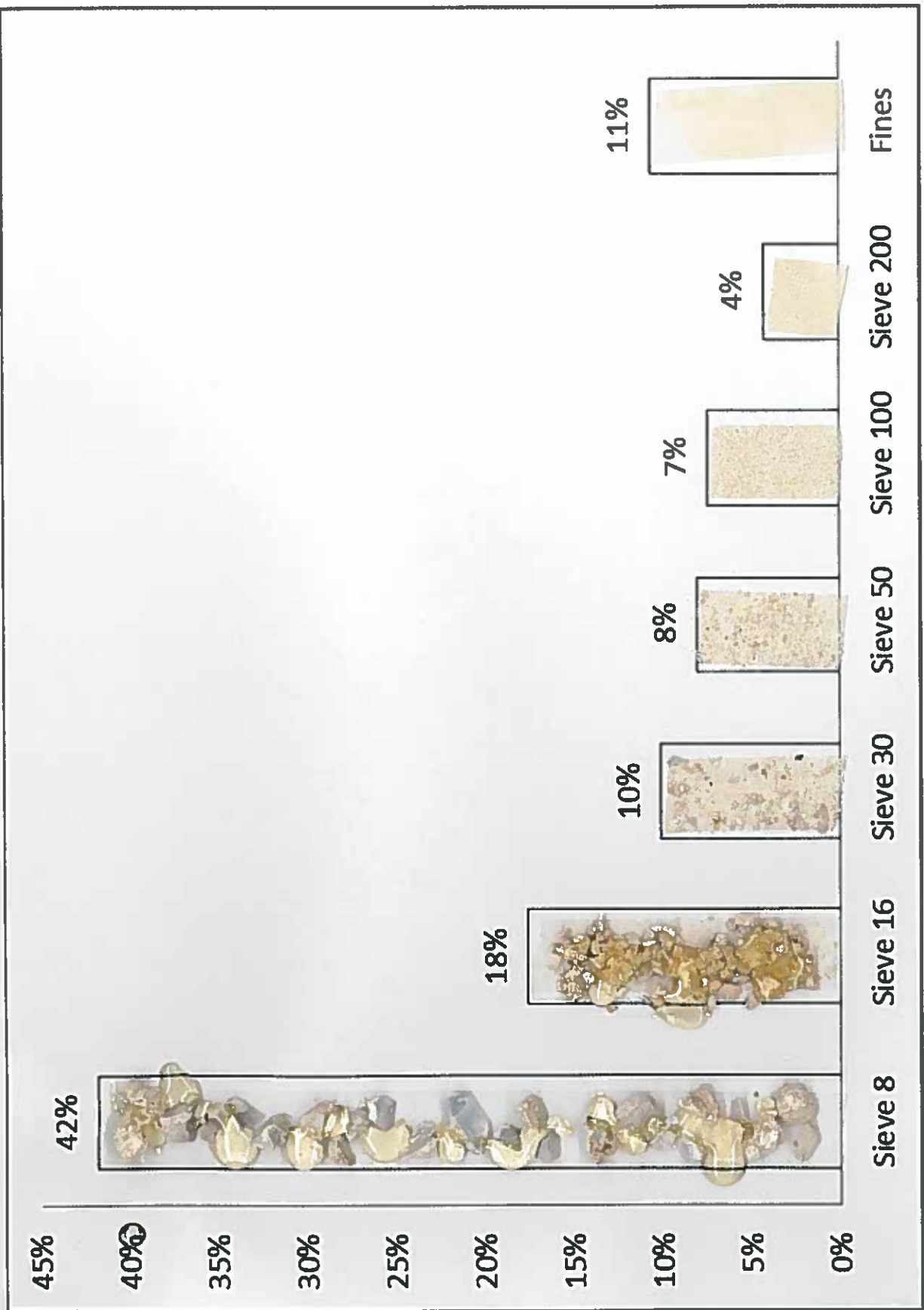
The mortar sample was crushed into a consistent size and weighed prior to dissolving the binder (calcium carbonates) from the sample using acid digestion. After diluting the acid, the remaining sample was filtered to separate the fines from the heavier aggregate. The two were then dried and weighed. The sieve method was used to separate the sand particles based on size. This is represented in the sand gradation chart. The best mortar mix produces a bell shaped gradation.



Mortar Analysis	
Original Weight of Sample	71.185 g
Weight of sample after digestion	41.3561 g
Acid Soluble Material	29.8289 g
Leaves a Mix Ratio of	3:2

Sand Grain Distribution		
2.36 mm – No. 8	17.2784 g	42 %
1.18 mm – No. 16	7.2931 g	18 %
600 Micro – No. 30	4.1774 g	10 %
300 Micro – No. 50	3.3388 g	8 %
150 Micro - No. 100	3.0824 g	7 %
75 Micro – No. 200	1.7760 g	4 %







Sample Constitution Avenue Bridge, Pointing Mortar Mortar Analysis for Fort Leonard Wood Preliminary Report

Report Date	August 2, 2016	Customer	Fort Leonard Wood
Company	National Center for Preservation Technology and Training	Site Address	Fort Leonard Wood MO, 65473
Address	645 University Parkway Natchitoches, LA 71457	Lab Technician	Jason Church

Introduction

In this document you will find the results of our laboratory testing on the mortar sample from Fort Leonard Wood Army Base. The samples were collected in the field by Jason Church in preparation of the preservation work that is planned for the on the masonry work done by German POWs during WWII.

This report is for Constitution Avenue Bridge at Parade Grounds, Pointing Mortar which was removed from the stone culvert lining the canal on the corner of Kansas and Missouri roads. (See lower picture on page 2). From the photograph it shows that the joints were washing out as the mortar begins to fail.

This mortar was mixed and laid in the 1940's at the early days of Portland Cement's popularity. The stone used is a locally quarried sand stone. No obvious signs of incompatibility are evident with the stone or in the mortar joints.

Description

Sample Constitution Avenue Bridge at Parade Grounds, Pointing Mortar was in two large separate pieces. The largest piece was 3" x 1"x 1". The samples have a concave tooled shape to the side that was exposed. This shows that the joints of the culvert all had a concave tooled shape. Overall the sample had a buff appearance with a mix of red hued aggregates. When the samples were sounded together they rang out sharply indicating a matrix of Portland. Due to the color this was likely White Portland.



Munsell Color Chart (Soil)		
Mortar sample before acid digestion appeared to be a very buff color.		
Hue	Value	Chroma
Yr		

Analysis

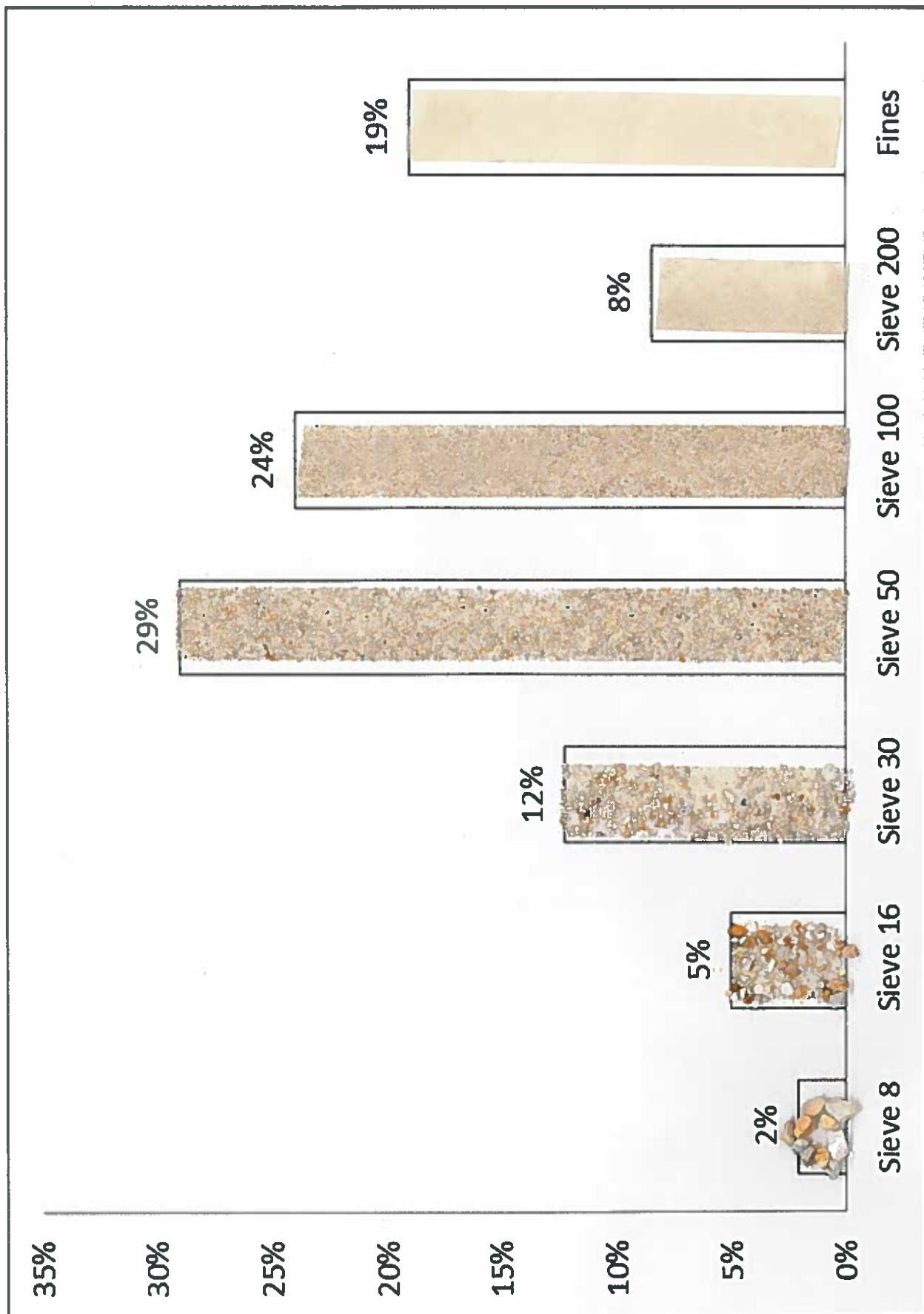
The mortar sample was crushed into a consistent size and weighed prior to dissolving the binder (calcium carbonates) from the sample using acid digestion. After diluting the acid, the remaining sample was filtered to separate the fines from the heavier aggregate. The two were then dried and weighed. The sieve method was used to separate the sand particles based on size. This is represented in the sand gradation chart. The best mortar mix produces a bell shaped gradation.



Mortar Analysis	
Original Weight of Sample	48.0045 g
Weight of sample after digestion	25.3130 g
Acid Soluble Material	22.6915 g
Leaves a Mix Ratio of	1:2

Sand Grain Distribution		
2.36 mm – No. 8	0.5378 g	2 %
1.18 mm – No. 16	1.2932 g	5 %
600 Micro – No. 30	3.1477 g	12 %
300 Micro – No. 50	7.4372 g	29 %
150 Micro - No. 100	6.1441 g	24 %
75 Micro – No. 200	2.1699 g	8 %





References

Technical Preservation Services



[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 2 Repointing Mortar Joints

Some of the web versions of the Preservation Briefs differ somewhat from the printed versions. Many illustrations are new and in color; Captions are simplified and some complex charts are omitted. To order hard copies of the Briefs, see [Printed Publications](#).

PRESERVATION BRIEFS

2

Repointing Mortar Joints in Historic Masonry Buildings

Robert C. Mack, FAIA, and John P. Speweik

[Historical Background](#)

[Identifying the Problem Before Repointing](#)

[Finding an Appropriate Mortar Match](#)

[Properties of Mortar](#)

[Mortar Analysis](#)

[Components of Mortar](#)

[Mortar Type and Mix](#)

[Budgeting and Scheduling](#)

[Contractor Selection](#)

[Execution of the Work](#)

[Visually Examining the Mortar and the Masonry Units](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)



Soft mortar for repointing. Photo: John P. Speweik.

Masonry—brick, stone, terra-cotta, and concrete block—is found on nearly every historic building. Structures with all-masonry exteriors come to mind immediately, but most other buildings at least have masonry foundations or chimneys. Although generally considered "permanent," masonry is subject to deterioration, especially at the mortar joints. Repointing, also known simply as "pointing" or—somewhat inaccurately—"tuck pointing"*, is the process of removing deteriorated mortar from the joints of a masonry wall and replacing it with new mortar. Properly done, repointing restores the visual and physical integrity of the masonry. Improperly done, repointing not only detracts from the appearance of the building, but may also cause physical damage to the masonry units themselves.

The purpose of this Brief is to provide general guidance on appropriate materials and methods for repointing historic masonry buildings and it is intended to benefit building owners, architects, and contractors. The Brief should serve as a guide to prepare specifications for repointing historic masonry buildings. It should also help develop sensitivity to the particular needs of historic masonry, and to assist historic building owners in working cooperatively with architects, architectural conservators and historic preservation consultants, and contractors. Although specifically intended for historic buildings, the guidance is appropriate for other masonry buildings as well. This publication updates *Preservation Briefs 2: Repointing Mortar Joints in Historic Brick Buildings* to include all types of historic unit masonry. The scope of the earlier Brief has also been expanded to acknowledge that the many buildings constructed in the first half of the 20th century are now

historic and eligible for listing in the National Register of Historic Places, and that they may have been originally constructed with portland cement mortar.

**Tuckpointing technically describes a primarily decorative application of a raised mortar joint or lime putty joint on top of flush mortar joints.*

Historical Background

Mortar consisting primarily of lime and sand has been used as an integral part of masonry structures for thousands of years. Up until about the mid-19th century, lime or quicklime (sometimes called lump lime) was delivered to construction sites, where it had to be slaked, or combined with water. Mixing with water caused it to boil and resulted in a wet lime putty that was left to mature in a pit or wooden box for several weeks, up to a year. Traditional mortar was made from lime putty, or slaked lime, combined with local sand, generally in a ratio of 1 part lime putty to 3 parts sand by volume. Often other ingredients, such as crushed marine shells (another source of lime), brick dust, clay, natural cements, pigments, and even animal hair were also added to mortar, but the basic formulation for lime putty and sand mortar remained unchanged for centuries until the advent of portland cement or its forerunner, Roman cement, a natural, hydraulic cement.

Portland cement was patented in Great Britain in 1824. It was named after the stone from Portland in Dorset which it resembled when hard. This is a fast-curing, hydraulic cement which hardens under water. Portland cement was first manufactured in the United States in 1872, although it was imported before this date. But it was not in common use throughout the country until the early 20th century. Up until the turn of the century portland cement was considered primarily an additive, or "minor ingredient" to help accelerate mortar set time. By the 1930s, however, most masons used a mix of equal parts portland cement and lime putty. Thus, the mortar found in masonry structures built between 1873 and 1930 can range from pure lime and sand mixes to a wide variety of lime, portland cement, and sand combinations.

In the 1930s more new mortar products intended to hasten and simplify masons' work were introduced in the U.S. These included **masonry cement**, a premixed, bagged mortar which is a combination of portland cement and ground limestone, and **hydrated lime**, machine-slaked lime that eliminated the necessity of slaking quicklime into putty at the site.

Identifying the Problem Before Repointing

The decision to repoint is most often related to some obvious sign of deterioration, such as disintegrating mortar, cracks in mortar joints, loose bricks or stones, damp walls, or damaged plasterwork. It is, however, erroneous to assume that repointing alone will solve deficiencies that result from other problems. The root cause of the deterioration—leaking roofs or gutters, differential settlement of the building, capillary action causing rising damp, or extreme weather exposure—should always be dealt with prior to beginning work.

Without appropriate repairs to eliminate the source of the problem, mortar deterioration will continue and any repointing will have been a waste of time and money.

Use of Consultants

Because there are so many possible causes for deterioration in historic buildings, it may be desirable to retain a consultant, such as a historic architect or architectural conservator, to analyze the building. In addition to determining the most appropriate solutions to the problems, a consultant can prepare specifications which reflect the particular requirements of each job and can provide oversight of the work in progress. Referrals to preservation consultants frequently can be obtained from State Historic Preservation Offices, the American Institute for Conservation of Historic and Artistic Works (AIC), the Association for Preservation Technology (APT), and local chapters of the American Institute of Architects (AIA).



Masons practice using lime putty mortar to repair historic marble. Photo: NPS files.

Finding an Appropriate Mortar Match

Preliminary research is necessary to ensure that the proposed repointing work is both physically and visually appropriate to the building. Analysis of unweathered portions of the historic mortar to which the new mortar will be matched can suggest appropriate mixes for the repointing mortar so that it will not damage the building because it is excessively strong or vapor impermeable.

Examination and analysis of the masonry units—brick, stone or terra cotta—and the techniques used in the original construction will assist in maintaining the building's historic appearance. A simple, non-technical, evaluation of the masonry units and mortar can provide information concerning the relative strength and permeability of each—critical factors in

selecting the repointing mortar—while a visual analysis of the historic mortar can provide the information necessary for developing the new mortar mix and application techniques.

Although not crucial to a successful repointing project, for projects involving properties of special historic significance, a mortar analysis by a qualified laboratory can be useful by providing information on the original ingredients. However, there are limitations with such an analysis, and replacement mortar specifications should not be based solely on laboratory analysis. Analysis requires interpretation, and there are important factors which affect the condition and performance of the mortar that cannot be established through laboratory analysis. These may include: the original water content, rate of curing, weather conditions during original construction, the method of mixing and placing the mortar, and the cleanliness and condition of the sand. *The most useful information that can come out of laboratory analysis is the identification of sand by gradation and color.* This allows the color and the texture of the mortar to be matched with some accuracy because sand is the largest ingredient by volume.



This late 19th century granite has recently been repointed with the joint profile and mortar color carefully matched to the original. Photo: NPS files.

In creating a repointing mortar that is compatible with the masonry units, the objective is to achieve one that matches the historic mortar as closely as possible, so that the new material can coexist with the old in a sympathetic, supportive and, if necessary, sacrificial capacity. The exact physical and chemical properties of the historic mortar are not of major significance as long as the new mortar conforms to the following criteria:

- The new mortar must match the historic mortar in **color, texture and tooling**. (If a laboratory analysis is undertaken, it may be possible to match the binder components and their proportions with the historic mortar, if those materials are available.)
- The **sand must match the sand** in the historic mortar. (The color and texture of the new mortar will usually fall into place if the sand is matched successfully.)
- The new mortar must have **greater vapor permeability** and be **softer** (measured in compressive strength) than the masonry units.
- The new mortar must be **as vapor permeable** and **as soft or softer** (measured in compressive strength) than the historic mortar. (Softness or hardness is not necessarily an indication of permeability; old, hard lime mortars can still retain high permeability.)

Mortar Analysis

Methods for analyzing mortars can be divided into two broad categories: **wet chemical** and **instrumental**. Many laboratories that analyze historic mortars use a simple **wet-chemical** method called acid digestion, whereby a sample of the mortar is crushed and then mixed with a dilute acid. The acid dissolves all the carbonate-containing minerals not only in the binder, but also in the aggregate (such as oyster shells, coral sands, or other carbonate-based materials), as well as any other acid-soluble materials. The sand and fine-grained acid-insoluble material is left behind. There are several variations on the simple acid digestion test. One involves collecting the carbon dioxide gas given off as the carbonate is digested by the acid; based on the gas volume the carbonate content of the mortar can be accurately determined (Jedrzejewska, 1960). Simple acid digestion methods are rapid, inexpensive, and easy to perform, but the information they provide about the original composition of a mortar is limited to the color and texture of the sand. The gas collection method provides more information about the binder than a simple acid digestion test.

Instrumental analysis methods that have been used to evaluate mortars include polarized light or thin-section microscopy, scanning electron microscopy, atomic absorption spectroscopy, X-ray diffraction, and differential thermal analysis. All instrumental methods require not only expensive, specialized equipment, but also highly-trained experienced analysts. However, instrumental methods can provide much more information about a mortar. Thin-section microscopy is probably the most commonly used instrumental method. Examination of thin slices of a mortar in transmitted light is often used to supplement acid digestion methods, particularly to look for carbonate-based aggregate. For example, the new ASTM test method, ASTM C 1324-96 "Test Method for Examination and Analysis of Hardened Mortars" which was designed specifically for the analysis of modern lime-cement and masonry cement mortars, combines a complex series of wet chemical analyses with thin-section microscopy.

The drawback of most mortar analysis methods is that mortar samples of known composition have not been analyzed in order to evaluate the method. Historic mortars were not prepared to narrowly defined specifications from materials of uniform quality; they contain a wide array of locally derived materials combined at the discretion of the mason. While a



This mortar is the proper consistency for repointing historic brick. Photo: John P. Speweik.

particular method might be able to accurately determine the original proportions of a lime-cement-sand mortar prepared from modern materials, the usefulness of that method for evaluating historic mortars is questionable unless it has been tested against mortars prepared from materials more commonly used in the past.

Properties of Mortar

Mortars for repointing should be softer or more permeable than the masonry units and no harder or more impermeable than the historic mortar to prevent damage to the masonry units. It is a common error to assume that hardness or high strength is a measure of appropriateness, particularly for lime-based historic mortars. Stresses within a wall caused by expansion, contraction, moisture migration, or settlement must be accommodated in some manner; in a masonry wall, these stresses should be relieved by the mortar rather than by the masonry units. A mortar that is stronger in compressive strength than the masonry units will not "give," thus causing stresses to be relieved through the masonry units—resulting in permanent damage to the masonry, such as cracking and spalling, that cannot be repaired easily.

While stresses can also break the bond between the mortar and the masonry units, permitting water to penetrate the resulting hairline cracks, this is easier to correct in the joint through repointing than if the break occurs in the masonry units.

Permeability, or rate of vapor transmission, is also critical. High lime mortars are more permeable than denser cement mortars. Historically, mortar acted as a bedding material—not unlike an expansion joint—rather than a "glue" for the masonry units, and moisture was able to migrate through the mortar joints rather than the masonry units. When moisture evaporates from the masonry it deposits any soluble salts either on the surface as *efflorescence* or below the surface as *subflorescence*. While salts deposited on the surface of masonry units are usually relatively harmless, salt crystallization within a masonry unit creates pressure that can cause parts of the outer surface to spall off or delaminate. If the mortar does not permit moisture or moisture vapor to migrate out of the wall and evaporate, the result will be damage to the masonry units.



This early 19th century building is being repointed with lime mortar. Photo: Travis McDonald.

Components of Mortar

Sand

Sand is the largest component of mortar and the material that gives mortar its distinctive color, texture and cohesiveness. Sand must be free of impurities, such as salts or clay. The three key characteristics of sand are: particle shape, gradation and void ratios.

When viewed under a magnifying glass or low-power microscope, particles of sand generally have either rounded edges, such as found in beach and river sand, or sharp, angular edges, found in crushed or manufactured sand. For repointing mortar, rounded or natural sand is preferred for two reasons. It is usually similar to the sand in the historic mortar and provides a better visual match. It also has better working qualities or plasticity and can thus be forced into the joint more easily, forming a good contact with the remaining historic mortar and the surface of the adjacent masonry units. Although manufactured sand is frequently more readily available, it is usually possible to locate a supply of rounded sand.

The gradation of the sand (particle size distribution) plays a very important role in the durability and cohesive properties of a mortar. Mortar must have a certain percentage of large to small particle sizes in order to deliver the optimum performance. Acceptable guidelines on particle size distribution may be found in ASTM C 144 (American Society for Testing and Materials). However, in actuality, since neither historic nor modern sands are always in compliance with ASTM C 144, matching the same particle appearance and gradation usually requires sieving the sand.

A scoop of sand contains many small voids between the individual grains. A mortar that performs well fills all these small voids with binder (cement/lime combination or mix) in a balanced manner. Well-graded sand generally has a 30 per cent void ratio by volume. Thus, 30 per cent binder by volume generally should be used, unless the historic mortar had a different binder: aggregate ratio. This represents the 1:3 binder to sand ratios often seen in mortar specifications.

For repointing, sand generally should conform to ASTM C 144 to assure proper gradation and freedom from impurities; some variation may be necessary to match the original size and gradation. Sand color and texture also should match the original as closely as possible to provide the proper color match without other additives.

Lime

Mortar formulations prior to the late-19th century used lime as the primary binding material. Lime is derived from heating limestone at high temperatures which burns off the carbon dioxide, and turns the limestone into quicklime. There are three types of limestone—calcium, magnesium, and dolomitic—differentiated by the different levels of magnesium carbonate they

contain which impart specific qualities to mortar. Historically, calcium lime was used for mortar rather than the dolomitic lime (calcium magnesium carbonate) most often used today. But it is also important to keep in mind the fact that the historic limes, and other components of mortar, varied a great deal because they were natural, as opposed to modern lime which is manufactured and, therefore, standardized. Because some of the kinds of lime, as well as other components of mortar, that were used historically are no longer readily available, even when a conscious effort is made to replicate a "historic" mix, this may not be achievable due to the differences between modern and historic materials.

Lime, itself, when mixed with water into a paste is very plastic and creamy. It will remain workable and soft indefinitely, if stored in a sealed container. Lime (calcium hydroxide) hardens by carbonation absorbing carbon dioxide primarily from the air, converting itself to calcium carbonate. Once a lime and sand mortar is mixed and placed in a wall, it begins the process of carbonation. If lime mortar is left to dry too rapidly, carbonation of the mortar will be reduced, resulting in poor adhesion and poor durability. In addition, lime mortar is slightly water soluble and thus is able to re-seal any hairline cracks that may develop during the life of the mortar. Lime mortar is soft, porous, and changes little in volume during temperature fluctuations thus making it a good choice for historic buildings. *Because of these qualities, high calcium lime mortar may be considered for many repointing projects, not just those involving historic buildings.*



Caulking was inappropriately used here in place of mortar on the top of the wall. As a result, it has not been durable. Photo: NPS files.

For repointing, lime should conform to ASTM C 207, Type S, or Type SA, Hydrated Lime for Masonry Purposes. This machine-slaked lime is designed to assure high plasticity and water retention. The use of quicklime which must be slaked and soaked by hand may have advantages over hydrated lime in some restoration projects if time and money allow.

Lime Putty

Lime putty is slaked lime that has a putty or paste-like consistency. It should conform to ASTM C 5. Mortar can be mixed using lime putty according to ASTM C 270 property or proportion specification.

Portland Cement

More recent, 20th-century mortar has used portland cement as a primary binding material. A straight portland cement and sand mortar is extremely hard, resists the movement of water, shrinks upon setting, and undergoes relatively large thermal movements. When mixed with water, portland cement forms a harsh, stiff paste that is quite unworkable, becoming hard very quickly. (Unlike lime, portland cement will harden regardless of weather conditions and does not require wetting and drying cycles.) Some portland cement assists the workability and plasticity of the mortar without adversely affecting the finished project; it also provides early strength to the mortar and speeds setting. Thus, it may be appropriate to add some portland cement to an essentially lime-based mortar even when repointing relatively soft 18th or 19th century brick under some circumstances when a slightly harder mortar is required. The more portland cement that is added to a mortar formulation the harder it becomes—and the faster the initial set.

For repointing, portland cement should conform to ASTM C 150. White, non-staining portland cement may provide a better color match for some historic mortars than the more commonly available grey portland cement. But, it should not be assumed, however, that white portland cement is always appropriate for all historic buildings, since the original mortar may have been mixed with grey cement. The cement should not have more than 0.60 per cent alkali to help avoid efflorescence.

Masonry Cement

Masonry cement is a preblended mortar mix commonly found at hardware and home repair stores. It is designed to produce mortars with a compressive strength of 750 psi or higher when mixed with sand and water at the job site. It may contain hydrated lime, but it always contains a large amount of portland cement, as well as ground limestone and other workability agents, including air-entraining agents. Because masonry cements are not required to contain hydrated lime, and generally do not contain lime, they produce high strength mortars that can damage historic masonry. *For this reason, they generally are not recommended for use on historic masonry buildings.*

Lime Mortar (pre-blended)

Hydrated lime mortars, and pre-blended lime putty mortars with or without a matched sand are commercially available. Custom mortars are also available with color. In most instances, pre-blended lime mortars containing sand may not provide an exact match; however, if the project calls for total repointing, a pre-blended lime mortar may be worth considering as long as the mortar is compatible in strength with the masonry. If the project involves only selected, "spot" repointing, then it may be better to carry out a mortar analysis which can provide a custom pre-blended lime mortar with a matching sand. In

either case, if a preblended lime mortar is to be used, it should contain Type S or SA hydrated lime conforming to ASTM C 207.

Water

Water should be potable—clean and free from acids, alkalis, or other dissolved organic materials.

Other Components

Historic components

In addition to the color of the sand, the texture of the mortar is of critical importance in duplicating historic mortar. Most mortars dating from the mid-19th century on—with some exceptions—have a fairly homogeneous texture and color. Some earlier mortars are not as uniformly textured and may contain lumps of partially burned lime or "dirty lime", shell (which often provided a source of lime, particularly in coastal areas), natural cements, pieces of clay, lampblack or other pigments, or even animal hair. The visual characteristics of these mortars can be duplicated through the use of similar materials in the repointing mortar.

Replicating such unique or individual mortars will require writing new specifications for each project. If possible, suggested sources for special materials should be included. For example, crushed oyster shells can be obtained in a variety of sizes from poultry supply dealers.

Pigments

Some historic mortars, particularly in the late 19th century, were tinted to match or contrast with the brick or stone. Red pigments, sometimes in the form of brick dust, as well as brown, and black pigments were commonly used. Modern pigments are available which can be added to the mortar at the job site, but they should not exceed 10 per cent by weight of the portland cement in the mix, and carbon black should be limited to 2 per cent. Only synthetic mineral oxides, which are alkali-proof and sun-fast, should be used to prevent bleaching and fading.

Modern Components

Admixtures are used to create specific characteristics in mortar, and whether they should be used will depend upon the individual project. *Air entraining agents*, for example, help the mortar to resist freeze-thaw damage in northern climates. *Accelerators* are used to reduce mortar freezing prior to setting while *retarders* help to extend the mortar life in hot climates. Selection of admixtures should be made by the architect or architectural conservator as part of the specifications, not something routinely added by the masons.

Generally, modern chemical additives are unnecessary and may, in fact, have detrimental effects in historic masonry projects. The use of antifreeze compounds is not recommended. They are not very effective with high lime mortars and may introduce salts, which may cause efflorescence later. A better practice is to warm the sand and water, and to protect the completed work from freezing. No definitive study has determined whether air-entraining additives should be used to resist frost action and enhance plasticity, but in areas of extreme exposure requiring high-strength mortars with lower permeability, air-entrainment of 10-16 percent may be desirable (see formula for "severe weather exposure" in Mortar Type and Mix). Bonding agents are not a substitute for proper joint preparation, and they should generally be avoided. If the joint is properly prepared, there will be a good bond between the new mortar and the adjacent surfaces. In addition, a bonding agent is difficult to remove if smeared on a masonry surface.

Mortar Type and Mix

Mortars for repointing projects, especially those involving historic buildings, typically are custom mixed in order to ensure the proper physical and visual qualities. These materials can be combined in varying proportions to create a mortar with the desired performance and durability. The actual specification of a particular mortar type should take into consideration all of the factors affecting the life of the building including: current site conditions, present condition of the masonry, function of the new mortar, degree of weather exposure, and skill of the mason.

Thus, no two repointing projects are exactly the same. Modern materials specified for use in repointing mortar should conform to specifications of the American Society for Testing and Materials (ASTM) or comparable federal specifications, and the resulting mortar should conform to ASTM C 270, Mortar for Unit Masonry.

Specifying the proportions for the repointing mortar for a specific job is not as difficult as it might seem. Five mortar types, each with a corresponding recommended mix, have been established by ASTM to distinguish high strength mortar from soft flexible mortars. The ASTM designated them in decreasing order of approximate general strength as Type M (2,500 psi), Type S (1,800 psi), Type N (750 psi), Type O (350 psi) and Type K (75 psi). (The letters identifying the types are from the words MASON WORK using every other letter.) Type K has the highest lime content of the mixes that contain portland cement, although it is seldom used today, except for some historic preservation projects. The designation "L" in the accompanying chart identifies a straight lime and sand mix. Specifying the appropriate ASTM mortar by proportion of



Here, a hammer and chisel are being correctly used to prepare a joint for repointing. Photo: John P. Speweik.

ingredients, will ensure the desired physical properties. Unless specified otherwise, measurements or proportions for mortar mixes are always given in the following order: cement-lime-sand. Thus, a Type K mix, for example, would be referred to as 1-3-10, or 1 part cement to 3 parts lime to 10 parts sand. Other requirements to create the desired visual qualities should be included in the specifications.

The strength of a mortar can vary. If mixed with higher amounts of portland cement, a harder mortar is obtained. The more lime that is added, the softer and more plastic the mortar becomes, increasing its workability. A mortar strong in compressive strength might be desirable for a hard stone (such as granite) pier holding up a bridge deck, whereas a softer, more permeable lime mortar would be preferable for a historic wall of soft brick. Masonry deterioration caused by salt deposition results when the mortar is less permeable than the masonry unit. A strong mortar is still more permeable than hard, dense stone. However, in a wall constructed of soft bricks where the masonry unit itself has a relatively high permeability or vapor transmission rate, a soft, high lime mortar is necessary to retain sufficient permeability.

Budgeting and Scheduling

Repointing is both expensive and time consuming due to the extent of handwork and special materials required. It is preferable to repoint only those areas that require work rather than an entire wall, as is often specified. But, if 25 to 50 per cent or more of a wall needs to be repointed, repointing the entire wall may be more cost effective than spot repointing.

Total repointing may also be more sensible when access is difficult, requiring the erection of expensive scaffolding (unless the majority of the mortar is sound and unlikely to require replacement in the foreseeable future). Each project requires judgement based on a variety of factors. Recognizing this at the outset will help to prevent many jobs from becoming prohibitively expensive.

In scheduling, seasonal aspects need to be considered first. Generally speaking, wall temperatures between 40 and 95 degrees F (8 and 38 degrees C) will prevent freezing or excessive evaporation of the water in the mortar. Ideally, repointing should be done in shade, away from strong sunlight in order to slow the drying process, especially during hot weather. If necessary, shade can be provided for large-scale projects with appropriate modifications to scaffolding.

The relationship of repointing to other work proposed on the building must also be recognized. For example, if paint removal or cleaning is anticipated, and if the mortar joints are basically sound and need only selective repointing, it is generally better to postpone repointing until after completion of these activities. However, if the mortar has eroded badly, allowing moisture to penetrate deeply into the wall, repointing should be accomplished before cleaning. Related work, such as structural or roof repairs, should be scheduled so that they do not interfere with repointing and so that all work can take maximum advantage of erected scaffolding.



When repairing this stone wall, the mason matched the raised profile of the original tuckpointing. Photo: NPS files.

Building managers also must recognize the difficulties that a repointing project can create. The process is time consuming, and scaffolding may need to remain in place for an extended period of time. The joint preparation process can be quite noisy and can generate large quantities of dust which must be controlled, especially at air intakes to protect human health, and also where it might damage operating machinery. Entrances may be blocked from time to time making access difficult for both building tenants and visitors. Clearly, building managers will need to coordinate the repointing work with other events at the site.

Contractor Selection

Contractor Selection The ideal way to select a contractor is to ask knowledgeable owners of recently repointed historic buildings for recommendations. Qualified contractors then can provide lists of other repointing projects for inspection. More commonly, however, the contractor for a repointing project is selected through a competitive bidding process over which the client or consultant has only limited control. In this situation it is important to ensure that the specifications stipulate that masons must have a minimum of five years' experience with repointing historic masonry buildings to be eligible to bid on the project. Contracts are awarded to the lowest responsible bidder, and bidders who have performed poorly on other projects usually can be eliminated from consideration on this basis, even if



A mechanical grinder improperly used to cut out the horizontal joint and incompatible repointing have seriously damaged the 19th century brick. Photo: NPS files.

they have the lowest prices.

The contract documents should call for unit prices as well as a base bid. Unit pricing forces the contractor to determine in advance what the cost addition or reduction will be for work which varies from the scope of the base bid. If, for example, the contractor has fifty linear feet less of stone repointing than indicated on the contract documents but thirty linear feet more of brick repointing, it will be easy to determine the final price for the work. Note that each type of work—brick repointing, stone repointing, or similar items—will have its own unit price. The unit price also should reflect quantities; one linear foot of pointing in five different spots will be more expensive than five contiguous linear feet.

Execution of the Work

Test Panels

These panels are prepared by the contractor using the same techniques that will be used on the remainder of the project. Several panel locations—preferably not on the front or other highly visible location of the building—may be necessary to include all types of masonry, joint styles, mortar colors, and other problems likely to be encountered on the job.



Unskilled repointing has negatively impacted the character of this late-19th century building. Photo: NPS files.

If cleaning tests, for example, are also to be undertaken, they should be carried out in the same location. Usually a 3 foot by 3 foot area is sufficient for brickwork, while a somewhat larger area may be required for stonework. These panels establish an acceptable standard of work and serve as a benchmark for evaluating and accepting subsequent work on the building.

Joint Preparation

Old mortar should be removed to a minimum depth of 2 to 2-1/2 times the width of the joint to ensure an adequate bond and to prevent mortar "popouts." For most brick joints, this will require removal of the mortar to a depth of approximately 1 to 1 1/2 inches; for stone masonry with wide joints, mortar may need to be removed to a depth of several inches. Any loose or disintegrated mortar beyond this minimum depth also should be removed.

Although some damage may be inevitable, careful joint preparation can help limit damage to masonry units. The traditional manner of removing old mortar is through the use of hand chisels and mash hammers. Though labor-intensive, in most instances this method poses the least threat for damage to historic masonry units and produces the best final product.

The most common method of removing mortar, however, is through the use of power saws or grinders. The use of power tools by unskilled masons can be disastrous for historic masonry, particularly soft brick. Using power saws on walls with thin joints, such as most brick walls, almost always will result in damage to the masonry units by breaking the edges and by overcutting on the head, or vertical joints.

However, small pneumatically-powered chisels generally can be used safely and effectively to remove mortar on historic buildings as long as the masons maintain appropriate control over the equipment. Under certain circumstances, thin diamond-bladed grinders may be used to cut out *horizontal* joints only on hard portland cement mortar common to most early-20th century masonry buildings. Usually, automatic tools most successfully remove old mortar without damaging the masonry units when they are used in combination with hand tools in preparation for repointing. Where horizontal joints are uniform and fairly wide, it may be possible to use a power masonry saw to assist the removal of mortar, such as by cutting along the middle of the joint; final mortar removal from the sides of the joints still should be done with a hand chisel and hammer. Caulking cutters with diamond blades can sometimes be used successfully to cut out joints without damaging the masonry. Caulking cutters are slow; they do not rotate, but vibrate at very high speeds, thus minimizing the possibility of damage to masonry units. Although mechanical tools may be safely used in limited circumstances to cut out horizontal joints in preparation for repointing, they should never be used on vertical joints because of the danger of slipping and cutting into the brick above or below the vertical joint. Using power tools to remove mortar without damaging the surrounding masonry units also necessitates highly skilled masons experienced in working on historic masonry buildings. Contractors should demonstrate proficiency with power tools before their use is approved.

Using any of these power tools may also be more acceptable on hard stone, such as quartzite or granite, than on terra cotta with its glass-like glaze, or on soft brick or stone. The test panel should determine the acceptability of power tools. If power tools are to be permitted, the contractor should establish a quality control program to account for worker fatigue and similar variables.

Mortar should be removed cleanly from the masonry units, leaving square corners at the back of the cut. Before filling, the joints should be rinsed with a jet of water to remove all loose particles and dust. At the time of filling, the joints should be damp, but with no standing water present. For masonry walls—limestone, sandstone and common brick—that are extremely absorbent, it is recommended that a continual mist of water be applied for a few hours before repointing begins.

Mortar Preparation

Mortar components should be measured and mixed carefully to assure the uniformity of visual and physical characteristics. Dry ingredients are measured by volume and thoroughly mixed before the addition of any water. Sand must be added in a damp, loose condition to avoid over sanding. Repointing mortar is typically pre-hydrated by adding water so it will just hold together, thus allowing it to stand for a period of time before the final water is added. Half the water should be added, followed by mixing for approximately 5 minutes. The remaining water should then be added in small portions until a mortar of the desired consistency is reached. The total volume of water necessary may vary from batch to batch, depending on weather conditions. It is important to keep the water to a minimum for two reasons: first, a drier mortar is cleaner to work with, and it can be compacted tightly into the joints; second, with no excess water to evaporate, the mortar cures without shrinkage cracks. Mortar should be used within approximately 30 minutes of final mixing, and "retempering," or adding more water, should not be permitted.

Using Lime Putty to Make Mortar

Mortar made with lime putty and sand, sometimes referred to as roughage or course stuff, should be measured by volume, and may require slightly different proportions from those used with hydrated lime. No additional water is usually needed to achieve a workable consistency because enough water is already contained in the putty. Sand is proportioned first, followed by the lime putty, then mixed for five minutes or until all the sand is thoroughly coated with the lime putty. But mixing, in the familiar sense of turning over with a hoe, sometimes may not be sufficient if the best possible performance is to be obtained from a lime putty mortar. Although the old practice of chopping, beating and ramming the mortar has largely been forgotten, recent field work has confirmed that lime putty and sand rammed and beaten with a wooden mallet or ax handle, interspersed by chopping with a hoe, can significantly improve workability and performance. The intensity of this action increases the overall lime/sand contact and removes any surplus water by compacting the other ingredients. It may also be advantageous for larger projects to use a mortar pan mill for mixing. Mortar pan mills which have a long tradition in Europe produce a superior lime putty mortar not attainable with today's modern paddle and drum type mixers.

For larger repointing projects the lime putty and sand can be mixed together ahead of time and stored indefinitely, on or off site, which eliminates the need for piles of sand on the job site. This mixture, which resembles damp brown sugar, must be protected from the air in sealed containers with a wet piece of burlap over the top or sealed in a large plastic bag to prevent evaporation and premature carbonation. The lime putty and sand mixture can be recombined into a workable plastic state months later with no additional water.

If portland cement is specified in a lime putty and sand mortar—Type O (1:2:9) or Type K (1:3:11)—the portland cement should first be mixed into a slurry paste before adding it to the lime putty and sand. Not only will this ensure that the portland cement is evenly distributed throughout the mixture, but if dry portland cement is added to wet ingredients it tends to "ball up," jeopardizing dispersion. (Usually water must be added to the lime putty and sand anyway once the portland cement is introduced.) Any color pigments should be added at this stage and mixed for a full five minutes. The mortar should be used within 30 minutes to 12 hours and it should not be retempered. Once portland cement has been added the mortar can no longer be stored.

Filling the Joint

Where existing mortar has been removed to a depth of greater than 1 inch, these deeper areas should be filled first, compacting the new mortar in several layers. The back of the entire joint should be filled successively by applying approximately 1/4 inch of mortar, packing it well into the back corners. This application may extend along the wall for several feet. As soon as the mortar has reached thumb-print hardness, another 1/4 inch layer of mortar—approximately the same thickness—may be applied. Several layers will be needed to fill the joint flush with the outer surface of the masonry. It is important to allow each layer time to harden before the next layer is applied; most of the mortar shrinkage occurs during the hardening process and layering thus minimizes overall shrinkage.

When the final layer of mortar is thumb-print hard, the joint should be tooled to match the historic joint. Proper timing of the tooling is important for uniform color and appearance. If tooled when too soft, the color will be lighter than expected, and hairline cracks may occur; if tooled when too hard, there may be dark streaks called "tool burning," and good closure of the mortar against the masonry units will not be achieved.

If the old bricks or stones have worn, rounded edges, it is best to recess the final mortar slightly from the face of the masonry. This treatment will help avoid a joint which is visually wider than the actual joint; it also will avoid creation of a large, thin featheredge which is easily damaged, thus admitting water. After tooling, excess mortar can be removed from the edge of the joint by brushing with a natural bristle or nylon brush. Metal bristle brushes should never be used on historic masonry.

Curing Conditions

The preliminary hardening of high-lime content mortars—those mortars that contain more lime by volume than portland cement, i.e., Type O (1:2:9), Type K (1:3:11), and straight lime/sand, Type "L" (0:1:3)—takes place fairly rapidly as water in the mix is lost to the porous surface of the masonry and through evaporation. A high lime mortar (especially Type "L") left to dry out too rapidly can result in chalking, poor adhesion, and poor durability. Periodic wetting of the repointed area after the mortar joints are thumb-print hard and have been finish tooled may significantly accelerate the carbonation process. When feasible, misting using a hand sprayer with a fine nozzle can be simple to do for a day or two after repointing. Local conditions will dictate the frequency of wetting, but initially it may be as often as every hour and gradually reduced to every three or four hours. Walls should be covered with burlap for the first three days after repointing. (Plastic may be used, but it should be tented out and not placed directly against the wall.) This helps keep the walls damp and protects them from direct sunlight. Once carbonation of the lime has begun, it will continue for many years and the lime will gain strength as it reverts back to calcium carbonate within the wall.

Aging the Mortar

Even with the best efforts at matching the existing mortar color, texture, and materials, there will usually be a visible difference between the old and new work, partly because the new mortar has been matched to the unweathered portions of the historic mortar. Another reason for a slight mismatch may be that the sand is more exposed in old mortar due to the slight erosion of the lime or cement. Although spot repointing is generally preferable and some color difference should be acceptable, if the difference between old and new mortar is too extreme, it may be advisable in some instances to repoint an entire area of a wall, or an entire feature such as a bay, to minimize the difference between the old and the new mortar. If the mortars have been properly matched, usually the best way to deal with surface color differences is to let the mortars age naturally. Other treatments to overcome these differences, including cleaning the non-repointed areas or staining the new mortar, should be carefully tested prior to implementation.



This 18th century pediment and surrounding wall exhibit distinctively different mortar joints. Photo: NPS files.

Staining the new mortar to achieve a better color match is generally not recommended, but it may be appropriate in some instances. Although staining may provide an initial match, the old and new mortars may weather at different rates, leading to visual differences after a few seasons. In addition, the mixtures used to stain the mortar may be harmful to the masonry; for example, they may introduce salts into the masonry which can lead to efflorescence.

Cleaning the Repointed Masonry

If repointing work is carefully executed, there will be little need for cleaning other than to remove the small amount of mortar from the edge of the joint following tooling. This can be done with a stiff natural bristle or nylon brush after the mortar has dried, but before it is initially set (1-2 hours). Mortar that has hardened can usually be removed with a wooden paddle or, if necessary, a chisel.

Further cleaning is best accomplished with plain water and natural bristle or nylon brushes. If chemicals must be used, they should be selected with extreme caution. Improper cleaning can lead to deterioration of the masonry units, deterioration of the mortar, mortar smear, and efflorescence. New mortar joints are especially susceptible to damage because they do not become fully cured for several months. Chemical cleaners, particularly acids, should never be used on dry masonry. The masonry should always be completely soaked once with water before chemicals are applied. After cleaning, the walls should be flushed again with plain water to remove all traces of the chemicals.

Several precautions should be taken if a freshly repointed masonry wall is to be cleaned. First, the mortar should be fully hardened before cleaning. Thirty days is usually sufficient, depending on weather and exposure; as mentioned previously, the mortar will continue to cure even after it has hardened. Test panels should be prepared to evaluate the effects of different cleaning methods. Generally, on newly repointed masonry walls, only very low pressure (100 psi) water washing supplemented by stiff natural bristle or nylon brushes should be used, except on glazed or polished surfaces, where only soft cloths should be used.**

New construction "bloom" or efflorescence occasionally appears within the first few months of repointing and usually disappears through the normal process of weathering. If the efflorescence is not removed by natural processes, the safest way to remove it is by dry brushing with stiff natural or nylon bristle brushes followed by wet brushing. Hydrochloric (muriatic) acid, is generally ineffective, and it should not be used to remove efflorescence. It may liberate additional salts, which, in turn, can lead to more efflorescence.

Surface grouting is sometimes suggested as an alternative to repointing brick buildings, in particular. This process involves the application of a thin coat of cement-based grout to the mortar joints and the mortar/brick interface. To be effective, the grout must extend slightly onto the face of the masonry units, thus widening the joint visually. The change in the joint appearance can alter the historic character of the structure to an unacceptable degree. In addition, although

masking of the bricks is intended to keep the grout off the remainder of the face of the bricks, some level of residue, called "veiling," will inevitably remain. Surface grouting cannot substitute for the more extensive work of repointing, and it is not a recommended treatment for historic masonry.

***Additional information on masonry cleaning is presented in Preservation Briefs 1: Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings, Robert C. Mack, FAIA, and Anne E. Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 2000; and Keeping it Clean: Removing Exterior Dirt, Paint, Stains & Graffiti from Historic Masonry Buildings, Anne E. Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 1988.*

Visually Examining the Mortar and the Masonry Units

A simple *in situ* comparison will help determine the hardness and condition of the mortar and the masonry units. Begin by scraping the mortar with a screwdriver, and gradually tapping harder with a cold chisel and mason's hammer. Masonry units can be tested in the same way beginning, even more gently, by scraping with a fingernail. This relative analysis which is derived from the 10-point hardness scale used to describe minerals, provides a good starting point for selection of an appropriate mortar. It is described more fully in "The Russack System for Brick & Mortar Description" referenced in [Reading List](#) at the end of this Brief.

Mortar samples should be chosen carefully, and picked from a variety of locations on the building to find unweathered mortar, if possible. Portions of the building may have been repointed in the past while other areas may be subject to conditions causing unusual deterioration. There may be several colors of mortar dating from different construction periods or sand used from different sources during the initial construction. Any of these situations can give false readings to the visual or physical characteristics required for the new mortar. Variations should be noted which may require developing more than one mix.

1. Remove with a chisel and hammer three or four unweathered samples of the mortar to be matched from several locations on the building. (Set the largest sample aside--this will be used later for comparison with the repointing mortar). Removing a full representation of samples will allow selection of a "mean" or average mortar sample.
2. Mash the remaining samples with a wooden mallet, or hammer if necessary, until they are separated into their constituent parts. There should be a good handful of the material.
3. Examine the powdered portion—the lime and/or cement matrix of the mortar. Most particularly, note the color. There is a tendency to think of historic mortars as having white binders, but grey portland cement was available by the last quarter of the 19th century, and traditional limes were also sometimes grey. Thus, in some instances, the natural color of the historic binder may be grey, rather than white. The mortar may also have been tinted to create a colored mortar, and this color should be identified at this point.
4. Carefully blow away the powdery material (the lime and/or cement matrix which bound the mortar together).
5. With a low power (10 power) magnifying glass, examine the remaining sand and other materials such as lumps of lime or shell.
6. Note and record the wide range of color as well as the varying sizes of the individual grains of sand, impurities, or other materials.

Other Factors to Consider

Color

Regardless of the color of the binder or colored additives, the sand is the primary material that gives mortar its color. A surprising variety of colors of sand may be found in a single sample of historic mortar, and the different sizes of the grains of sand or other materials, such as incompletely ground lime or cement, play an important role in the texture of the repointing mortar. Therefore, when specifying sand for repointing mortar, it may be necessary to obtain sand from several sources and to combine or screen them in order to approximate the range of sand colors and grain sizes in the historic mortar sample.

Pointing Style

Close examination of the historic masonry wall and the techniques used in the original construction will assist in maintaining the visual qualities of the building. Pointing styles and the methods of producing them should be examined. It is important to look at both the horizontal and the vertical joints to determine the order in which they were tooled and whether they were the same style. Some late-19th and early-20th century buildings, for example, have horizontal joints that were raked back

while the vertical joints were finished flush and stained to match the bricks, thus creating the illusion of horizontal bands. Pointing styles may also differ from one facade to another; front walls often received greater attention to mortar detailing than side and rear walls. **Tuckpointing** is not true repointing but the application of a raised joint or lime putty joint on top of flush mortar joints. **Penciling** is a purely decorative, painted surface treatment over a mortar joint, often in a contrasting color.

Masonry Units

The masonry units should also be examined so that any replacement units will match the historic masonry. Within a wall there may be a wide range of colors, textures, and sizes, particularly with hand-made brick or rough-cut, locally-quarried stone. Replacement units should blend in with the full range of masonry units rather than a single brick or stone.

Matching Color and Texture of the Repointing Mortar

New mortar should match the unweathered interior portions of the historic mortar. The simplest way to check the match is to make a small sample of the proposed mix and allow it to cure at a temperature of approximately 70 degrees F for about a week, or it can be baked in an oven to speed up the curing; this sample is then broken open and the surface is compared with the surface of the largest "saved" sample of historic mortar.

If a proper color match cannot be achieved through the use of natural sand or colored aggregates like crushed marble or brick dust, it may be necessary to use a modern mortar pigment.

During the early stages of the project, it should be determined how closely the new mortar should match the historic mortar. Will "quite close" be sufficient, or is "exactly" expected? The specifications should state this clearly so that the contractor has a reasonable idea how much time and expense will be required to develop an acceptable match.

The same judgment will be necessary in matching replacement terra cotta, stone or brick. If there is a known source for replacements, this should be included in the specifications. If a source cannot be determined prior to the bidding process, the specifications should include an estimated price for the replacement materials with the final price based on the actual cost to the contractor.

Mortar Types (Measured by volume)

Designation	Cement	Hydrated Lime or Lime Putty	Sand
M	1	1/4	3 - 3 3/4
S	1	1/2	4-4 1/2
N	1	1	5-6
O	1	2	8-9
K	1	3	10-12
"L"	0	1	2 1/4-3

Suggested Mortar Types for Different Exposures

Masonry Material	Exposure		
	Sheltered	Moderate	Severe
Very durable: granite, hard-cored brick, etc.	O	N	S
Moderately durable:limestone, durable stone, molded brick	K	O	N
Minimally durable:soft hand-made brick	"L"	K	O

Summary and References

For the Owner/Administrator

The owner or administrator of a historic building should remember that repointing is likely to be a lengthy and expensive process. First, there must be adequate time for evaluation of the building and investigation into the cause of problems. Then, there will be time needed for preparation of the contract documents. The work itself is precise, time-consuming and

noisy, and scaffolding may cover the face of the building for some time. Therefore, the owner must carefully plan the work to avoid problems. Schedules for both repointing and other activities will thus require careful coordination to avoid unanticipated conflicts. The owner must avoid the tendency to rush the work or cut corners if the historic building is to retain its visual integrity and the job is to be durable.

For the Architect/Consultant

Because the primary role of the consultant is to ensure the life of the building, a knowledge of historic construction techniques and the special problems found in older buildings is essential. The consultant must assist the owner in planning for logistical problems relating to research and construction. It is the consultant's responsibility to determine the cause of the mortar deterioration and ensure that it is corrected before the masonry is repointed. The consultant must also be prepared to spend more time in project inspections than is customary in modern construction.

For the Masons

Successful repointing depends on the masons themselves. Experienced masons understand the special requirements for work on historic buildings and the added time and expense they require. The entire masonry crew must be willing and able to perform the work in conformance with the specifications, even when the specifications may not be in conformance with standard practice. At the same time, the masons should not hesitate to question the specifications if it appears that the work specified would damage the building.

Conclusion

A good repointing job is meant to last, at least 30 years, and preferably 50- 100 years. Shortcuts and poor craftsmanship result not only in diminishing the historic character of a building, but also in a job that looks bad, and will require future repointing sooner than if the work had been done correctly. The mortar joint in a historic masonry building has often been called a wall's "first line of defense." Good repointing practices guarantee the long life of the mortar joint, the wall, and the historic structure. Although careful maintenance will help preserve the freshly repointed mortar joints, it is important to remember that mortar joints are intended to be sacrificial and will probably require repointing some time in the future. Nevertheless, if the historic mortar joints proved durable for many years, then careful repointing should have an equally long life, ultimately contributing to the preservation of the entire building.

Useful Addresses

Brick Institute of America

11490 Commerce Park Drive
Reston, VA 22091

National Lime Association

200 N. Glebe Road, Suite 800
Arlington, VA 22203

Portland Cement Association

5420 Old Orchard Road
Skokie, IL 60077

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[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 6 Dangers of Abrasive Cleaning

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PRESERVATION BRIEFS

6

Dangers of Abrasive Cleaning to Historic Buildings

Anne E. Grimmer

[What is Abrasive Cleaning?](#)

[Why are Abrasive Cleaning Methods Used?](#)

[Problems of Abrasive Cleaning](#)

[How Building Materials React to Abrasive Cleaning](#)

[When is Abrasive Cleaning Permissible?](#)

[Do Not Abrasively Clean these Historic Interiors](#)

[Mitigating the Effects of Abrasive Cleaning](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)



Undamaged historic brick (above).
Sandblasted brick (below). Photo:
Courtesy, Illinois Historic Preservation
Agency.

“Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.” —**The Secretary of the Interior’s Standards for Rehabilitation.**

Abrasive cleaning methods are responsible for causing a great deal of damage to historic building materials.

To prevent indiscriminate use of these potentially harmful techniques, this brief has been prepared to explain abrasive cleaning methods, how they can be physically and aesthetically destructive to historic building materials, and why they generally are not acceptable preservation treatments for historic structures. There are alternative, less harsh means of cleaning and removing paint and stains from historic buildings. However, careful testing should precede general cleaning to assure that the method selected will not have an adverse effect on the building materials. A historic building is irreplaceable, and should be cleaned using only the "gentlest means possible" to best preserve it.

What is Abrasive Cleaning?

Abrasive cleaning methods include all techniques that physically abrade the building surface to remove soils, discolorations or coatings. Such techniques involve the use of certain *materials* which impact or abrade the surface under pressure, or *abrasive tools and equipment*. Sand, because it is readily available, is probably the most commonly used type of grit material. However, any of the following materials may be substituted for sand, and all can be classified as abrasive substances: ground slag or volcanic ash, crushed (pulverized) walnut or almond shells, rice husks, ground corncobs, ground coconut shells, crushed eggshells, silica flour, synthetic particles, glass beads and micro-balloons. Even *water* under pressure can be an abrasive substance. Tools and equipment that are abrasive to historic building materials include wire

brushes, rotary wheels, power sanding disks and belt sanders.

The use of water in combination with grit may also be classified as an abrasive cleaning method. Depending on the manner in which it is applied, water may soften the impact of the grit, but water that is too highly pressurized can be very abrasive. There are basically two different methods which can be referred to as "wet grit," and it is important to differentiate between the two. One technique involves the addition of a stream of water to a regular sandblasting nozzle. This is done primarily to cut down dust, and has very little, if any, effect on reducing the aggressiveness, or cutting action of the grit particles. With the second technique, a very small amount of grit is added to a pressurized water stream. This method may be controlled by regulating the amount of grit fed into the water stream, as well as the pressure of the water.

Why Are Abrasive Cleaning Methods Used?

Usually, an abrasive cleaning method is selected as an expeditious means of quickly removing years of dirt accumulation, unsightly stains, or deteriorating building fabric or finishes, such as stucco or paint.



Abrasive cleaning can cause permanent damage to historic fabric, such as this brick wall. Photo: NPS files.

The fact that sandblasting is one of the best known and most readily available building cleaning treatments is probably the major reason for its frequent use.

Many mid-19th century brick buildings were painted immediately or soon after completion to protect poor quality brick or to imitate another material, such as stone. Sometimes brick buildings were painted in an effort to produce what was considered a more harmonious relationship between a building and its natural surroundings. By the 1870s, brick buildings were often left unpainted as mechanization in the brick industry brought a cheaper pressed brick and fashion decreed a sudden preference for dark colors. However, it was still customary to paint brick of poorer quality for the additional protection the paint afforded.

It is a common 20th century misconception that all historic masonry buildings were initially unpainted. If the intent of a modern restoration is to return a building to its original appearance, removal of the paint not only may be historically inaccurate, but also harmful. Many older buildings were painted or stuccoed at some point to correct recurring maintenance problems caused by faulty construction techniques, to hide alterations, or in an attempt to solve moisture problems. If this is the case, removal of paint or stucco may cause these problems to reoccur.



Brick molding next to the window has been severely abraded by sandblasting to remove paint. Photo: NPS files.

Another reason for paint removal, particularly in rehabilitation projects, is to give the building a "new image" in response to contemporary design trends and to attract investors or tenants. Thus, it is necessary to consider the purpose of the intended cleaning. While it is clearly important to remove unsightly stains, heavy encrustations of dirt, peeling paint or other surface coatings, it may not be equally desirable to remove paint from a building which originally was painted. Many historic buildings which show only a slight amount of soil or discoloration are much better left as they are.

A thin layer of soil is more often protective of the building fabric than it is harmful, and seldom detracts from the building's architectural and/or historic character. Too thorough cleaning of a historic building may not only sacrifice some of the building's character, but also, misguided cleaning efforts can cause a great deal of damage to historic building fabric. Unless there are stains, graffiti or dirt and pollution deposits which are destroying the building fabric, it is generally preferable to do as little cleaning as possible, or to repaint where necessary. It is important to remember that a historic building does not have to look as if it were newly constructed to be an attractive or successful restoration or rehabilitation project.

Problems of Abrasive Cleaning

The crux of the problem is that abrasive cleaning is just that--abrasive. An abrasively cleaned historic structure may be physically as well as aesthetically damaged. Abrasive methods "clean" by eroding dirt or paint, but at the same time they also tend to erode the surface of the building material. In this way, abrasive cleaning is destructive and causes irreversible harm to the historic building fabric. If the fabric is brick, abrasive methods remove the hard, outer protective surface, and therefore make the brick more susceptible to rapid weathering and deterioration.

Grit blasting may also increase the water permeability of a brick wall. The impact of the grit particles tends to erode the bond between the mortar and the brick, leaving cracks or enlarging existing cracks where water can enter. Some types of stone develop a protective patina or "quarry crust" parallel to the worked surface (created by the movement of moisture towards the outer edge), which also may be damaged by abrasive cleaning. The rate at which the material subsequently weathers depends on the quality of the inner surface that is exposed.

Abrasive cleaning can destroy, or substantially diminish, decorative detailing on buildings such as a molded brickwork or architectural terra-cotta, ornamental carving on wood or stone, and evidence of historic craft techniques, such as tool marks and other surface textures.

In addition, perfectly sound and/or "tooled" mortar joints can be worn away by abrasive techniques. This not only results in the loss of historic craft detailing but also requires repointing, a step involving considerable time, skill and expense, and which might not have been necessary had a gentler method been chosen. Erosion and pitting of the building material by abrasive cleaning creates a greater surface area on which dirt and pollutants collect. In this sense, the building fabric "attracts" more dirt, and will require more frequent cleaning in the future.

In addition to causing physical and aesthetic harm to the historic fabric, there are several adverse environmental effects of dry abrasive cleaning methods. Because of the friction caused by the abrasive medium hitting the building fabric, these techniques usually create a considerable amount of dust, which is unhealthy, particularly to the operators of the abrasive equipment. It further pollutes the environment around the job site, and deposits dust on neighboring buildings, parked vehicles and nearby trees and shrubbery. Some adjacent materials not intended for abrasive treatment such as wood or glass, may also be damaged because the equipment may be difficult to regulate.

Wet grit methods, while eliminating dust, deposit a messy slurry on the ground or other objects surrounding the base of the building. In colder climates where there is the threat of frost, any wet cleaning process applied to historic masonry structures must be done in warm weather, allowing ample time for the wall to dry out thoroughly before cold weather sets in. Water which remains and freezes in cracks and openings of the masonry surface eventually may lead to spalling. High-pressure wet cleaning may force an inordinate amount of water into the walls, affecting interior materials such as plaster or joist ends, as well as metal building components within the walls.

Variable Factors

The greatest problem in developing practical guidelines for cleaning any historic building is the large number of variable and unpredictable factors involved. Because these variables make each cleaning project unique, it is difficult to establish specific standards at this time. This is particularly true of abrasive cleaning methods because their inherent potential for causing damage is multiplied by the following factors:

- the type and condition of the material being cleaned
- the size and sharpness of the grit particles or the mechanical equipment
- the pressure with which the abrasive grit or equipment is applied to the building surface
- the skill and care of the operator, and
- the constancy of the pressure on all surfaces during the cleaning process.

Pressure: The damaging effects of most of the variable factors involved in abrasive cleaning are self evident. However, the matter of pressure requires further explanation. In cleaning specifications, pressure is generally abbreviated as "psi" (pounds per square inch), which technically refers to the "tip" pressure, or the amount of pressure at the nozzle of the blasting apparatus. Sometimes "psig," or pressure at the gauge (which may be many feet away, at the other end of the hose), is used in place of "psi." These terms are often incorrectly used interchangeably.

Despite the apparent care taken by most architects and building cleaning contractors to prepare specifications for pressure cleaning which will not cause harm to the delicate fabric of a historic building, it is very difficult to ensure that the same amount of pressure is applied to all parts of the building. For example, if the operator of the pressure equipment stands on the ground while cleaning a two-story structure, the amount of force reaching the first story will be greater than that hitting the second story, even if the operator stands on scaffolding or in a cherry picker, because of the "line drop" in the distance from the pressure source to the nozzle. Although technically it may be possible to prepare cleaning specifications with tight controls that would eliminate all but a small margin of error, it may not be easy to find professional cleaning firms willing to work under such restrictive conditions. The fact is that many professional building cleaning firms do not really understand the extreme delicacy of historic building fabric, and how it differs from modern construction materials. Consequently, they may accept building cleaning projects for which they have no experience.

The amount of pressure used in any kind of cleaning treatment which involves pressure, whether it is dry or wet grit, chemicals or just plain water, is crucial to the outcome of the cleaning project. Unfortunately, no standards have been established for determining the correct pressure for cleaning each of the many historic building materials which would not



On the left, grit blasting has obliterated the vertical tooling marks from granite, a very dense stone. Photo: NPS files.



Bronze statuary may be cleaned gently using crushed walnut shells.
Photo: NPS files.

cause harm. The considerable discrepancy between the way the building cleaning industry and architectural conservators define "high" and "low" pressure cleaning plays a significant role in the difficulty of creating standards.

Non-historic/Industrial: A representative of the building cleaning industry might consider "high" pressure water cleaning to be anything over 5,000 psi, or even as high as 10,000 to 15,000 psi! Water under this much pressure may be necessary to clean industrial structures or machinery, but would destroy most historic building materials. Industrial chemical cleaning commonly utilizes pressures between 1,000 and 2,500 psi.

Historic: By contrast, conscientious dry or wet abrasive cleaning of a historic structure would be conducted within the range of 20 to 100 psi at a range of 3 to 12 inches. Cleaning at this low pressure requires the use of a very fine 00 or 0 mesh grit forced through a nozzle with a 1/4-inch opening. A similar, even more delicate method being adopted by architectural conservators uses a micro-abrasive grit on small, hard-to-clean areas of carved, cut or molded ornament on a building facade. Originally developed by museum conservators for cleaning sculpture, this technique may employ glass beads, micro-balloons, or another type of micro-abrasive gently powered at

approximately 40 psi by a very small, almost pencil-like pressure instrument. Although a slightly larger pressure instrument may be used on historic buildings, this technique still has limited practical applicability on a large scale building cleaning project because of the cost and the relatively few technicians competent to handle the task. In general, architectural conservators have determined that only through very controlled conditions can most historic building material be abrasively cleaned of soil or paint without measurable damage to the surface or profile of the substrate.

Yet some professional cleaning companies which specialize in cleaning historic masonry buildings use chemicals and water at a pressure of approximately 1,500 psi, while other cleaning firms recommend lower pressures ranging from 200 to 800 psi for a similar project. An architectural conservator might decide, after testing, that some historic structures could be cleaned properly using a moderate pressure (200-600 psi), or even a high pressure (600-1800 psi) water rinse. However, cleaning historic buildings under such high pressure should be considered an exception rather than the rule, and would require *very careful* testing and supervision to assure that the historic surface materials could withstand the pressure without gouging, pitting or loosening.

These differences in the amount of pressure used by commercial or industrial building cleaners and architectural conservators point to one of the main problems in using abrasive means to clean historic buildings: misunderstanding of the potentially fragile nature of historic building materials. There is no one cleaning formula or pressure suitable for all situations. Decisions regarding the proper cleaning process for historic structures can be made only after careful analysis of the building fabric, and testing.

How Building Materials React to Abrasive Cleaning

Brick and Architectural Terra-cotta: Abrasive blasting does not affect all building materials to the same degree. Such techniques quite logically cause greater damage to softer and more porous materials, such as brick or architectural terra-cotta. When these materials are cleaned abrasively, the hard, outer layer (closest to the heat of the kiln) is eroded, leaving the soft, inner core exposed and susceptible to accelerated weathering. Glazed architectural terra-cotta and ceramic veneer have a baked on glaze which is also easily damaged by abrasive cleaning. Glazed architectural terra-cotta was designed for easy maintenance, and generally can be cleaned using detergent and water; but chemicals or steam may be needed to remove more persistent stains. Large areas of brick or architectural terra-cotta which have been painted are best left painted, or repainted if necessary.

Plaster and Stucco: Plaster and stucco are types of masonry finish materials that are softer than brick or terra-cotta; if treated abrasively these materials will simply disintegrate. Indeed, when plaster or stucco is treated abrasively it is usually with the intention of removing the plaster or stucco from whatever base material or substrate it is covering. Obviously, such abrasive techniques should not be applied to clean sound plaster or stuccoed walls, or decorative plaster wall surfaces.

Building Stones: Building stones are cut from the three main categories of natural rock: dense, igneous rock such as granite; sandy, sedimentary rock such as limestone or sandstone; and crystalline, metamorphic rock such as marble. As opposed to kiln-dried masonry materials such as brick and architectural terra-cotta, building stones are generally homogeneous in character at the time of a building's construction. However, as the stone is exposed to weathering and environmental pollutants, the surface may become friable, or may develop a protective skin or patina. These outer surfaces are very susceptible to damage by abrasive or improper chemical cleaning.

Building stones are frequently cut into ashlar blocks or "dressed" with tool marks that give the building surface a specific texture and contribute to its historic character as much as ornately carved decorative stonework. Such detailing is easily

damaged by abrasive cleaning techniques; the pattern of tooling or cutting is erased, and the crisp lines of moldings or carving are worn or pitted.

Occasionally, it may be possible to clean small areas of rough-cut granite, limestone or sandstone having a heavy dirt encrustation by using the "wet grit" method, whereby a small amount of abrasive material is injected into a controlled, pressurized water stream. However, this technique requires very careful supervision in order to prevent damage to the stone. Polished or honed marble or granite should never be treated abrasively, as the abrasion would remove the finish in much the way glass would be etched or "frosted" by such a process. It is generally preferable to underclean, as too strong a cleaning procedure will erode the stone, exposing a new and increased surface area to collect atmospheric moisture and dirt. Removing paint, stains or graffiti from most types of stone may be accomplished by a chemical treatment carefully selected to best handle the removal of the particular type of paint or stain without damaging the stone. (See section on the "Gentlest Means Possible.")



Very high-pressure water has scarred this granite.
Photo: NPS files.

Wood: Most types of wood used for buildings are soft, fibrous and porous, and are particularly susceptible to damage by abrasive cleaning. Because the summer wood between the lines of the grain is softer than the grain itself, it will be worn away by abrasive blasting or power tools, leaving an uneven surface with the grain raised and often frayed or "fuzzy." Once this has occurred, it is almost impossible to achieve a smooth surface again except by extensive hand sanding, which is expensive and will quickly negate any costs saved earlier by sandblasting. Such harsh cleaning treatment also obliterates historic tool marks, fine carving and detailing, which precludes its use on any interior or exterior woodwork which has been hand planed, milled or carved.

Metals: Like stone, metals are another group of building materials which vary considerably in hardness and durability. Softer metals which are used architecturally, such as tin, zinc, lead, copper or aluminum, generally should not be cleaned abrasively as the process deforms and destroys the original surface texture and appearance, as well as the acquired patina.



Decorative pressed metal interior or exterior features should not be cleaned abrasively. Photo: NPS files.

Much applied architectural metal work used on historic buildings--tin, zinc, lead and copper--is often quite thin and soft, and therefore susceptible to denting and pitting. Galvanized sheet metal is especially vulnerable, as abrasive treatment would wear away the protective galvanized layer.

In the late 19th and early 20th centuries, these metals were often cut, pressed or otherwise shaped from sheets of metal into a wide variety of practical uses such as roofs, gutters and flashing, and facade ornamentation such as cornices, friezes, dormers, panels, cupolas, oriel windows, etc. The architecture of the 1920s and 1930s made use of metals such as chrome, nickel alloys, aluminum and stainless steel in decorative exterior panels, window frames, and doorways. Harsh abrasive blasting would destroy the original surface finish of most of these metals, and would increase the possibility of corrosion.

However, conservation specialists are now employing a sensitive technique of glass bead peening to clean some of the harder metals, in particular large bronze outdoor sculpture. Very fine (75125 micron) glass beads are used at a low pressure of 60 to 80 psi. Because these glass beads are completely spherical, there are no sharp edges to cut the surface of the metal. After cleaning, these

statues undergo a lengthy process of polishing. Coatings are applied which protect the surface from corrosion, but they must be renewed every 3 to 5 years. A similarly delicate cleaning technique employing glass beads has been used in Europe to clean historic masonry structures without causing damage. But at this time the process has not been tested sufficiently in the United States to recommend it as a building conservation measure.

Sometimes a very fine smooth sand is used at a low pressure to clean or remove paint and corrosion from copper flashing and other metal building components. Restoration architects recently found that a mixture of crushed walnut shells and copper slag at a pressure of approximately 200 psi was the only way to remove corrosion successfully from a mid-19th century terne-coated iron roof. Metal cleaned in this manner must be painted immediately to prevent rapid recurrence of corrosion. It is thought that these methods "work harden" the surface by compressing the outer layer, and actually may be good for the surface of the metal. But the extremely complex nature and the time required by such processes make it very expensive and impractical for large-scale use at this time.

Cast and wrought iron architectural elements may be gently sandblasted or abrasively cleaned using a wire brush to remove layers of paint, rust and corrosion. Sandblasting was, in fact, developed originally as an efficient maintenance procedure for engineering and industrial structures and heavy machinery--iron and steel bridges, machine tool frames, engine frames, and railroad rolling stock--in order to clean and prepare them for repainting. Because iron is hard, its surface, which is naturally somewhat uneven, will not be noticeably damaged by controlled abrasion. Such treatment will, however, result in a

small amount of pitting. But this slight abrasion creates a good surface for paint, since the iron must be repainted immediately to prevent corrosion. Any abrasive cleaning of metal building components will also remove the caulking from joints and around other openings. Such areas must be recaulked quickly to prevent moisture from entering and rusting the metal, or causing deterioration of other building fabric inside the structure.

When is Abrasive Cleaning Permissible?

For the most part, abrasive cleaning is destructive to historic building materials. A limited number of special cases have been explained when it may be appropriate, if supervised by a skilled conservator, to use a delicate abrasive technique on some historic building materials. The type of "wet grit" cleaning which involves a small amount of grit injected into a stream of low pressure water may be used on small areas of stone masonry (i.e., rough cut limestone, sandstone or unpolished granite), where milder cleaning methods have not been totally successful in removing harmful deposits of dirt and pollutants. Such areas may include stone window sills, the tops of cornices or column capitals, or other detailed areas of the facade.

This is still an abrasive technique, and without proper caution in handling, it can be *just as harmful to the building surface as any other abrasive cleaning method*. Thus, the decision to use this type of "wet grit" process should be made only after consultation with an experienced building conservator. *Remember that it is very time consuming and expensive to use any abrasive technique on a historic building in such a manner that it does not cause harm to the often fragile and friable building materials.*

At this time, and only under certain circumstances, abrasive cleaning methods may be used in the rehabilitation of interior spaces of warehouse or industrial buildings for contemporary uses.

Interior spaces of factories or warehouse structures in which the masonry or plaster surfaces do not have significant design, detailing, tooling or finish, and in which wooden architectural features are not finished, molded, beaded or worked by hand, may be cleaned abrasively in order to remove layers of paint and industrial discolorations such as smoke, soot, etc. It is expected after such treatment that brick surfaces will be rough and pitted, and wood will be somewhat frayed or "fuzzy" with raised wood grain. These nonsignificant surfaces will be damaged and have a roughened texture, but because they are interior elements, they will not be subject to further deterioration caused by weathering.

Historic Interiors That Should Not Be Cleaned Abrasively

Those instances (generally industrial and some commercial properties), when it may be acceptable to use an abrasive treatment on the interior of historic structures have been described. But for the majority of historic buildings, the Secretary of the Interior's *Guidelines for Rehabilitation* do not recommend "changing the texture of exposed wooden architectural features (including structural members) and masonry surfaces through sandblasting or use of other abrasive techniques to remove paint, discolorations and plaster.

Thus, it is not acceptable to clean abrasively interiors of historic residential and commercial properties which have *finished* interior spaces featuring milled woodwork such as doors, window and door moldings, wainscoting, stair balustrades and mantelpieces. Even the most modest historic house interior, although it may not feature elaborate detailing, contains plaster and woodwork that is architecturally significant to the original design and function of the house. Abrasive cleaning of such an interior would be destructive to the historic integrity of the building.

Abrasive cleaning is also impractical. Rough surfaces of abrasively cleaned wooden elements are hard to keep clean. It is also difficult to seal, paint or maintain these surfaces which can be splintery and a problem to the building's occupants. The force of abrasive blasting may cause grit particles to lodge in cracks of wooden elements, which will be a nuisance as the grit is loosened by vibrations and gradually sifts out. Removal of plaster will reduce the thermal and insulating value of the



Cast iron may be abrasively cleaned, but must be painted immediately to prevent rust. Photo: NPS files.



Industrial interiors that are not finely milled may be abrasively cleaned, in some instances. Photo: NPS files.



Decorative wood exterior or interior features should not be cleaned abrasively. Photo: NPS files.

walls. Interior brick is usually softer than exterior brick, and generally of a poorer quality. Removing surface plaster from such brick by abrasive means often exposes gaping mortar joints and mismatched or repaired brickwork which was never intended to show. The resulting bare brick wall may require repointing, often difficult to match. It also may be necessary to apply a transparent surface coating (or sealer) in order to prevent the mortar and brick from "dusting." However, a sealer may not only change the color of the brick, but may also compound any existing moisture problems by restricting the normal evaporation of water vapor from the masonry surface.

"Gentlest Means Possible"

There are alternative means of removing dirt, stains and paint from historic building surfaces that can be recommended as more efficient and less destructive than abrasive techniques. The "gentlest means possible" of removing dirt from a building surface can be achieved by using a low-pressure water wash, scrubbing areas of more persistent grime with a natural bristle (never metal) brush. Steam cleaning can also be used effectively to clean some historic building fabric. Low-pressure water or steam will soften the dirt and cause the deposits to rise to the surface, where they can be washed away.

A third cleaning technique which may be recommended to remove dirt, as well as stains, graffiti or paint, involves the use of commercially available chemical cleaners or paint removers, which, when applied to masonry, loosen or dissolve the dirt or stains. These cleaning agents may be used in combination with water or steam, followed by a clear water wash to remove the residue of dirt and the chemical cleaners from the masonry. A natural bristle brush may also facilitate this type of chemically assisted cleaning, particularly in areas of heavy dirt deposits or stains, and a wooden scraper can be useful in removing thick encrustations of soot. A limewash or absorbent talc, whitening or clay poultice with a solvent can be used effectively to draw out salts or stains from the surface of the selected areas of a building facade. It is almost impossible to remove paint from masonry surfaces without causing some damage to the masonry, and it is best to leave the surfaces as they are or repaint them if necessary.

Some physicists are experimenting with the use of pulsed laser beams and xenon flash lamps for cleaning historic masonry surfaces. At this time it is a slow, expensive cleaning method, but its initial success indicates that it may have an increasingly important role in the future.

There are many chemical paint removers which, when applied to painted wood, soften and dissolve the paint so that it can be scraped off by hand. Peeling paint can be removed from wood by hand scraping and sanding. Particularly thick layers of paint may be softened with a heat gun or heat plate, providing appropriate precautions are taken, and the paint film scraped off by hand. Too much heat applied to the same spot can burn the wood, and the fumes caused by burning paint are dangerous to inhale, and can be explosive. Furthermore, the hot air from heat guns can start fires in the building cavity. Thus, adequate ventilation is important when using a heat gun or heat plate, as well as when using a chemical stripper. A torch or open flame should never be used.

Preparations for Cleaning: It cannot be overemphasized that all of these cleaning methods must be approached with caution. When using any of these procedures which involve water or other liquid cleaning agents on masonry, it is imperative that all openings be tightly covered, and all cracks or joints be well pointed in order to avoid the danger of water penetrating the building's facade, a circumstance which might result in serious moisture related problems such as efflorescence and/or subflorescence. Any time water is used on masonry as a cleaning agent, either in its pure state or in combination with chemical cleaners, it is very important that the work be done in warm weather when there is no danger of frost for several months. Otherwise water which has penetrated the masonry may freeze, eventually causing the surface of the building to crack and spall, which may create another conservation problem more serious to the health of the building than dirt.

Each kind of masonry has a unique composition and reacts differently with various chemical cleaning substances. Water and/or chemicals may interact with minerals in stone and cause new types of stains to leach out to the surface immediately, or more gradually in a delayed reaction. What may be a safe and effective cleaner for certain stain on one type of stone, may leave unattractive discolorations on another stone, or totally dissolve a third type.

Testing: Cleaning historic building materials, particularly masonry, is a technically complex subject, and thus, should never be done without expert consultation and testing. No cleaning project should be undertaken without first applying the intended cleaning agent to a representative test patch area in an inconspicuous location on the building surface. The test patch or patches should be allowed to weather for a period of time, preferably through a complete seasonal cycle, in order to determine that the cleaned area will not be adversely affected by wet or freezing weather or any by-products of the cleaning process.

Mitigating the Effects of Abrasive Cleaning

There are certain restoration measures which can be adopted to help preserve a historic building exterior which has been damaged by abrasive methods. Wood that has been sandblasted will exhibit a frayed or "fuzzed" surface, or a harder wood

will have an exaggerated raised grain. The only way to remove this rough surface or to smooth the grain is by laborious sanding. Sandblasted wood, unless it has been extensively sanded, serves as a dustcatcher, will weather faster, and will present a continuing and ever worsening maintenance problem. Such wood, after sanding, should be painted or given a clear surface coating to protect the wood, and allow for somewhat easier maintenance.

There are few successful preservative treatments that may be applied to grit-blasted exterior masonry. Harder, denser stone may have suffered only a loss of crisp edges or tool marks, or other indications of craft technique. If the stone has a compact and uniform composition, it should continue to weather with little additional deterioration. But some types of sandstone, marble and limestone will weather at an accelerated rate once their protective "quarry crust" or patina has been removed.

Softer types of masonry, particularly brick and architectural terra-cotta, are the most likely to require some remedial treatment if they have been abrasively cleaned. Old brick, being essentially a soft, baked clay product, is greatly susceptible to increased deterioration when its hard, outer skin is removed through abrasive techniques. This problem can be minimized by painting the brick. An alternative is to treat it with a clear sealer or surface coating but this will give the masonry a glossy, or shiny look. It is usually preferable to paint the brick rather than to apply a transparent sealer since sealers reduce the transpiration of moisture, allowing salts to crystallize as subflorescence that eventually spalls the brick. If a brick surface has been so extensively damaged by abrasive cleaning and weathering that spalling has already begun, it may be necessary to cover the walls with stucco, if it will adhere.

Of course, the application of paint, a clear surface coating (sealer), or stucco to deteriorating masonry means that the historical appearance will be sacrificed in an attempt to conserve the historic building materials. However, the original color and texture will have been changed already by the abrasive treatment. At this point it is more important to try to preserve the brick, and there is little choice but to protect it from "dusting" or spalling too rapidly. As a last resort, in the case of severely spalling brick, there may be no option but to replace the brick--a difficult, expensive (particularly if custom-made reproduction brick is used), and lengthy process. As described earlier, sandblasted interior brick work, while not subject to change of weather, may require the application of a transparent surface coating or painting as a maintenance procedure to contain loose mortar and brick dust. (See [Preservation Briefs No. 1](#) for a more thorough discussion of coatings.)

Metals, other than cast or wrought iron, that have been pitted and dented by harsh abrasive blasting usually cannot be smoothed out. Although fillers may be satisfactory for smoothing a painted surface, exposed metal that has been damaged usually will have to be replaced.

Summary and References

Sandblasting or other abrasive methods of cleaning or paint removal are by their nature destructive to historic building materials and should not be used on historic buildings except in a few well-monitored instances. There are exceptions when certain types of abrasive cleaning may be permissible, but only if conducted by a trained conservator, and if cleaning is necessary for the preservation of the historic structure.

There is no one formula that will be suitable for cleaning all historic building surfaces. Although there are many commercial cleaning products and methods available, it is impossible to state definitively which of these will be the most effective without causing harm to the building fabric. It is often difficult to identify ingredients or their proportions contained in cleaning products; consequently it is hard to predict how a product will react to the building materials to be cleaned. Similar uncertainties affect the outcome of other cleaning methods as they are applied to historic building materials. Further advances in understanding the complex nature of the many variables of the cleaning techniques may someday provide a better and simpler solution to the problems. But until that time, the process of cleaning historic buildings must be approached with caution through trial and error.

It is important to remember that historic building materials are neither indestructible, nor are they renewable. They must be treated in a responsible manner, which may mean little or no cleaning at all if they are to be preserved for future generations to enjoy. If it is in the best interest of the building to clean it, then it should be done "using the gentlest means possible."

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Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

June 1979

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PROGRAM COMMENT FOR DEPARTMENT OF DEFENSE REHABILITATION TREATMENT MEASURES

APPENDIX 2

SECTION 04100.02 PREPARATION OF LIME AND CEMENT-AMENDED MORTARS

PART 1 - GENERAL

1.01 DESCRIPTION

- A. This specification provides procedures appropriate for preparing lime and cement-amended mortars for use in repointing historic masonry.
- B. This specification has been developed for use on historic properties (defined as any district, site, building, structure, or object that is listed in or is eligible for listing in the National Register of Historic Places) and provides an overview of accepted practices.
- C. All work described herein and related work must conform to the Secretary of the Interior's Standards for the Treatment of Historic Properties.
- D. The Contractor shall provide all labor, materials, equipment, and operations required to complete the rehabilitation work indicated herein.
- E. All work described herein and related work must have the approval of a Cultural Resources Manager, Conservator, Historic Architect, or other professional who meets the standards outlined in the Secretary of the Interior's Standards – Professional Qualifications Standards pursuant to 36 CFR 61. Such person is referred to in this document as the *Architect*.
- F. Site-specific specifications, when appropriate, will be provided by the Architect.

1.02 SECTION INCLUDES

- A. Mortar selection
- B. Preparation of lime mortar
- C. Preparation of cement-amended mortar

1.03 RELATED SECTIONS

- A. Section 04100.01 – Removal of Mortar Joints and Repointing
- B. Section 04211 – Historic Brick (pending issuance)
- C. Section 04214 – Terra Cotta and Ceramics (pending issuance)
- D. Section 04400.01 – Identifying Masonry Types and Failures
- E. Section 04500 – Masonry Restoration (pending issuance)

1.04 REFERENCES

- A. *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, available at the National Park Service (NPS) website at <http://www.nps.gov/history/hps/tps/standards_guidelines.htm>.
- B. Use and types of mortar are found in *Preservation Brief No. 2: Repointing Masonry Joints in Historic Masonry Building*, available online at the NPS website at <<http://www.nps.gov/history/hps/tps/briefs/brief02.htm>>.
- C. U.S. General Services Administration Historic Preservation Technical Procedures for Mortar, available online at <http://w3.gsa.gov/web/p/hptp.nsf/a533f1f859737bc9852565cc0058d0b6/7de342045d4c63f6852565c50054b3a7?OpenDocument> and <<http://w3.gsa.gov/web/p/hptp.nsf/a533f1f859737bc9852565cc0058d0b6/e7518da3d776f026852565c50054b3c5?OpenDocument>>.
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- E. ASTM C207, *Standard Specification for Hydrated Lime for Masonry Purposes*
- F. ASTM C206, *Standard Specification for Finishing Hydrated Lime*
- G. ASTM C144, *Standard Specification for Aggregate for Masonry Mortar*.
- H. ASTM C150, Type II, *Standard Specification for Portland Cement*.
- I. ASTM C979, *Specification for Pigments for Integrally Pigmented Concrete*.
- J. ASTM C170 – Compressive Strength of Natural Building Stone
- K. ASTM C5 Standard Specification for Quicklime for Structural Purposes

1.05 SUBMITTALS

- A. The Contractor shall submit a detailed schedule of the areas to be repointed, including an assessment of the problem areas, a historic mortar analysis, and a detailed procedure for repointing, to the Architect for approval:
 - 1. Submit data indicating proportion or property specifications used for mortar.
 - 2. Submit test reports for mortar materials and report proportions resulting from laboratory testing used to select mortar mix.
- B. Product Literature: The Contractor shall submit the manufacturer's product literature to the Architect for all proprietary products specified for repointing. Product literature shall include specification data, Material Safety Data Sheets, and instructions for storage, handling, and use.
- C. Historic Mortar Analysis: The Contractor shall submit the laboratory report from completed mortar analysis. Mortar analysis shall be completed prior to beginning test-panel preparation. At a minimum, analysis shall be a wet chemical and microscopic

analysis to characterize the insoluble aggregate, determine binder-aggregate ratio, prepare a mix design for replacement mortar, and identify appropriate sources for sand aggregate. If circumstances so dictate it, the Architect shall require the contractor to submit alternate mortar analyses, such as X-ray diffraction.

- D. Samples: No masonry restoration work shall proceed until all samples are approved by the Architect. The Contractor shall submit samples of the following masonry repair and replacement materials for approval of color and texture match:

Cured pointing mortar. Portable samples shall be prepared using drywall channel or similar material the approximate width of a mortar joint. Once a matching mortar color is achieved, placement of on-site mock-ups may begin.

1.06 QUALITY ASSURANCE

- A. Work Experience: The Contractor and Masons to perform the work in this section shall have demonstrated experience approved by the Architect, ideally a minimum of ten (10) years experience with historic mortars and masonry repairs and repointing. He/she shall demonstrate a working knowledge of the Secretary of the Interior's Standards for Guidelines for Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings.
- B. The Contractor shall not change sources or manufacturers of mortar materials during the course of the work.

1.07 MOCK-UPS

- A. The Contractor shall prepare two mock-up installations of each type of mortar color for each type of masonry to be installed at locations selected by the Architect. If cleaning tests are also to take place, test panels should be in the same area. Test panels should not be undertaken in areas that are highly visible.
- B. Each test panel shall be executed in the same manner as the final installation. Test panels shall be a minimum area of 3x3 feet for brick facades, and larger for stone facades.
- C. After the test panels have cured for a period of two to three weeks (or otherwise specified by the Architect), the test panels will be inspected for color, texture, and installation technique.
- D. If the Architect finds the first two mock-ups unacceptable, the Contractor shall prepare up to three additional mock-ups of each mortar and mortar color without further compensation. Test area(s) approved by the Architect shall become part of the work and shall serve as the quality standard for all subsequent work.

1.08 DELIVERY, STORAGE, AND HANDLING

- A. The Contractor shall deliver all products to the site in original packaging, unopened and undamaged, with manufacturer's name and product identification visible thereon and manufacturer's instructions and Material Safety Data Sheets.
- B. The Contractor shall store products in a dry location and protect them from dampness and freezing following manufacturer's instructions.

- C. The Contractor shall stockpile and handle aggregates in a manner to prevent contamination from foreign materials.

1.09 PROJECT / SITE CONDITIONS

- A. Mortar installation shall be executed only when the air and surface temperatures are 40 degrees F and rising or less than 80 degrees F and falling. Minimum temperature for masonry repointing shall be 50 degrees F and above for at least 2 hours after completion and above freezing for at least 24 hours after completion. Work shall not commence when rain, snow, or below-freezing temperatures are expected within the next 24 hours. All surfaces shall be free of standing water, frost, and ice.
- B. The Contractor is responsible for protecting existing adjacent materials and surfaces during the execution of the work, and will provide all necessary protection and follow all necessary work procedures to avoid damage to existing material assemblies not a part of the work in the Section.
- C. The Contractor shall provide visible barriers and / or warning tape around the perimeter of the work area for visitor protection, and shall also provide that nearby vehicles and adjacent structures and foliage are protected from damage during the course of the work.
- D. Contractor shall coordinate masonry repointing with the other trades involved in exterior and interior rehabilitation work, including but not limited to masonry cleaning, sealing, and painting.

PART 2 - PRODUCTS

2.01 MORTAR SELECTION CRITERIA: See Sections 04100.02 and 04400.01.

- A. Repair mortar shall be compatible with the material, quality, color, strength and texture of the existing mortar.
- B. Sand shall match the gradation of the historic mortar and be free from impurities. The color, size, and texture of the sand should be similar to the original sand.
- C. Mortar shall have greater vapor permeability and be softer, measured in compressive strength, than the masonry units.
- D. Mortar shall be as vapor permeable and be as soft or softer, measured in compressive strength, than the existing historic mortar.
- E. Testing and Mortar Selection for Masonry Units:
 - 1. Selection of Mortar for Brick Units:
 - a. Identify type and strength of brick.
 - b. Identify the composition, strength, and hardness of the historic mortar.
 - c. Lime and Sand mortars are preferred for historic brick masonry.

- d. Portland cement generally should not be used for historic brick, depending on historic resource.
 - e. Mortar should have a lower compressive (psi) strength than brick.
- 2. Selection of Mortar for Terra Cotta and Ceramic Units:
 - a. Mortar should have a lower compressive (psi) strength than the terra cotta and ceramic units.
 - b. Hard, portland cements or coarsely screened mortars shall not be used, depending on the historic resource.
- 3. Stone:
 - a. Identify type of stone.
 - b. Identify geological and mineralogical nature of stone.
 - c. Identify the Compressive or Crushing Strength of stone both wet and dry: ASTM C170-87 – Compressive Strength of Natural Building Stone.
 - d. Mortar should have a lower compressive (psi) strength than stone: general about 1/3 the compressive or crushing strength of the stone units.
 - e. Hard, portland cements are generally not appropriate for historic mortars, depending on the historic resource.
- 4. Concrete Block and Cast Stone Units:
 - a. Mortar should have a lower compressive (psi) strength than the masonry units.
 - b. Use of concrete amended mortars, when appropriate.

2.02 MORTAR TYPE AND MIX

- A. Depending on the desired strength and consistency, lime mortars should conform to ASTM C207 and ASTM C206, Mortar for Masonry, such as:
 - 1. Type M (2,500 psi): 3:1:12
 - 2. Type S (1,800 psi): 2:1:9
 - 3. Type N (750 psi): 1:1:6
 - 4. Type O (350 psi): 1:2:9
 - 5. Type K (75 psi): 1:3:11
 - 6. Type L: 0:1:3

OR

- B. Equivalent mortar that meets comparable federal specifications.

2.03 POINTING MATERIALS AND MIXES (JOB-MIXED MORTAR)

- A. Portland cement: ASTM C150, Type I, non-staining and without air entrainment. Gray and white Portland cement may be combined as required to match the desired color.
 - 1. Non-staining white cement, preferred for historic applications, unless grey cement was used in the original mortar.
- B. Hydrated Lime: ASTM C207, Type S.
- C. Lime Putty (slaked lime): should conform to ASTM C5.
- D. Sand: ASTM C144 Standard Specification for Aggregate for Masonry Mortar, free of clay, silt, soluble salts, and organic matter; shall match the color, size gradation, and texture of the original mortar sand. The Contractor may request from the Architect a sample of the original mortar sand, when available, for use in color and texture matching.
- E. Water: Potable, free from injurious amounts of oil, soluble salts, alkali, acids, organic impurities and other deleterious substances which impair mortar strength or bonding.
- F. Masonry Cement (premixed, bagged mortar): shall NOT be used.

2.04 PRE-MIXED MORTARS: Pre-mixed mortars that have been designed for use on historic buildings may be used for repointing. All such mortars must be approved by the Architect.

2.05 ACCESSORY MATERIALS

- A. Historic Materials include other components that enhance the color and texture matching and may include materials such as crushed oyster shells and animal hair, and historic pigments such as brick dust and lamp black.
- B. Colorants (if required for exact color match): Non-fading, mineral oxide masonry pigment as approved by the Architect.
 - 1. Pigments should not exceed 10% by weight of the portland cement in the mix.
 - 2. Carbon black should not exceed 2% of the Portland cement in the mix.

2.06 ADMIXTURES

- A. No air-entraining admixtures or material containing air-entraining admixtures shall be added to the mortar.
- B. No antifreeze compounds shall be added to mortar.
- C. No admixtures containing chlorides shall be added to mortar.

2.07 EQUIPMENT FOR MORTAR PREPARATION

- A. Equipment:

1. Trough, plastic buckets, hoe, wooden mallet, or similar implements
2. Mortar pan mill
3. Paddle or drum type mixers
4. Undyed, unprinted burlap

PART 3 – EXECUTION

3.01 GENERAL

- A. Testing and Mortar Selection shall be approved by the Architect. The Contractor shall submit testing schedule, mortar schedule, and schedule of related repairs, including methods and materials to be used:
 1. Identify masonry units: Type and composition.
 2. Identify the crushing or compressive strength (psi) of masonry units.
 3. Identify properties, composition, and strength of historic mortar.
 4. Select mortars that match the existing in color, texture, quality, and materials.
 5. Select mortars that are softer than the existing mortar and the masonry units.
- B. Mortar components should be measured and mixed carefully (in a consistent manner) to assure uniformity of visual and physical characteristics.
- C. Pre-mixed mortar should be mixed and handled following manufacturer's specifications.

3.02 FIELD MIXING FOR LIME MORTARS

- A. Measure dry ingredients by volume.
- B. In a clean trough, wheelbarrow, or mixer (depending on quantities needed) combine and mix all dry ingredients thoroughly (before adding water).
- C. Add just enough clean water to "hold together," thus allowing the mixture to stand for a period prior to the addition of the remaining water.
- D. Prior to use, add half of the water and mix thoroughly for five (5) minutes.
- E. Add the remaining water in small portions until the desired consistency is reached. Keep the amount of water added to a minimum.
- F. Mortar should be used within approximately 30 minutes of final mixing. Do not retemper or add more water after final mixing.

3.03 FIELD MIXING FOR MORTAR USING LIME PUTTY

- A. Materials are measured by volume.

- B. Do not add additional water.
- C. Proportion sand first, and then add the lime putty.
- D. Mix in a clean trough for five (5) minutes or until all the sand is thoroughly coated with the lime putty by beating with a wood mallet, interspersed by chopping with a hoe to achieve the maximum workability and performance.

OR

- E. Mix in a mortar pan mill when large quantities are needed, following the sequence above. Modern paddle and drum mixers do not achieve the desired results.
- F. Protect the mixture from the air by covering with wet burlap or seal in a large plastic bag.
- G. The sand/lime putty mix can be stored indefinitely if placed in a sealed bag or container. Recombine mixture as specified in D above into a workable plastic state. *Do not add water.*

3.04 FIELD MIXING FOR PORTLAND CEMENT –LIME PUTTY-SAND MORTARS (Type O or Type K)

- A. Materials are measured by volume.
- B. Combine sand and lime putty as described above and mix. Do not add water at this point.
- C. Mix the portland cement into a slurry paste using clean water.
- D. Combine the portland cement slurry with the sand/lime putty mixture.
- E. Add color pigments, if any.
- F. Mix for five (5) minutes.
- G. Mixture should be used within 30 minutes to 1 ½ hours. Do not retemper mixture. Once portland cement is added, the mortar can no longer be stored.

3.05 FINAL REPORT

The Contractor and Architect shall:

- A. Document the work, testing, and mortar mixes used, and finished product, including photographs (both ‘before’ and ‘after’) and final mortar schedules.
- B. Provide a written summary of the project and results upon final inspection and approval. The summary shall outline steps taken or new findings not specified in the initial documentation.

END OF SECTION

PART 1 - GENERAL**1.01 DESCRIPTION**

- A. This specification provides guidance for cleaning historic masonry materials, including the removal of soiling, staining, graffiti, and biogrowth.
- B. This specification has been developed for use on historic properties (defined as any district, site, building, structure, or object that is listed in or eligible for listing in the National Register of Historic Places) and provides an overview of accepted practices. Site-specific specifications, when appropriate, will be provided by the Architect.
- C. All work described herein and related work must conform to the Secretary of the Interior's Standards for the Treatment of Historic Properties.
- D. The Contractor shall provide all labor, material, equipment, and operations required to complete the rehabilitation work indicated herein.
- E. All work described herein and related work must have the approval of a Cultural Resources Manager, Conservator, Historic Architect, or other professional who meets the standards outlined in the Secretary of the Interior's Standards – Professional Qualifications Standards pursuant to 36 CFR 61. Such person is referred to in this document as the *Architect*.

1.02 SECTION INCLUDES

- A. Cleaning of soiling.
- B. Cleaning of staining and graffiti.
- C. Cleaning of biological growth and bird droppings.

1.03 RELATED SECTIONS

- A. Section 03710.01 – Concrete Cleaning: Removal of Atmospheric Soiling, Graffiti, Staining, and Biogrowth.
- B. Section 04100.01 – Removal of Mortar Joints and Repointing
- C. Section 04110.02 – Repair and Replacement of Historic Stucco
- D. Section 04211.01 – Historic Brick Properties and In Kind Replacement
- E. Section 04214.02 – Terracotta Patching and Glaze Repair
- F. Section 04510.03 – Poulticing and Salt Removal

1.04 DEFINITIONS

- A. Atmospheric Soiling: The dust, aerosols, and particulate matter deposited from the air directly on the material surface. Particulates can result from vehicle exhaust, sea salts and other contaminants.
- B. Biological soiling: Discolorations that include biological growth (biogrowth) and biological deposits. Biogrowth includes microorganisms, including lichens, bacteria, algae, fungi, and molds that discolor the material surface. Factors influencing biogrowth include exposure, orientation, position, and the material's surface texture. Deposited material, such as bird droppings, aphid "honey dew," and others, are considered biological soiling.
- C. Chemical Cleaning: Cleaning methods that involve applying a substance to the material that interacts with the material and any discoloration on the surface. Chemical cleaning methods may include water, organic solvents, and alkaline or acidic chemicals.
- D. Cleaning Test Patch: A small unobtrusive area, usually less than 6 inch by 6 inch, in which the Contractor tests a particular cleaning method. Several cleaning test patches are usually performed side by side to directly compare methods.
- E. Complexing and Sequestering agent: an organic chemical that acts to grab and bind metals to itself.
- F. Detergent: any chemical substance, other than soap, that is an effective cleanser and functions equally well as a surface-active agent in hard or soft water.
- G. Graffiti: Usually an unwanted painting or marking in any manner on property.
- H. Physical Cleaning: Physical cleaning methods generally involve the removal of material from the surface using abrasive methods. Physical methods include pressure washing at low and medium pressures, and mechanical or manual brushing.
- I. Poultice: The term poultice is extended to a wide range of cleaning materials and techniques. In general, it is a cleaning method that involves the application of a mixture of a cleaner and an absorbent substance to a surface to draw out contaminants and stains from the surface of a material.
- J. Staining: a penetrating discoloration or soiled spot found on the material.

1.05 REFERENCES

- A. Masonry cleaning shall conform to National Park Service's *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, 1992. National Park Service. 28 July 2009.
<http://www.nps.gov/history/hps/tps/standards_guidelines.htm>
- B. Where applicable, techniques employed for treatment shall be as outlined in the following *Preservation Briefs*, published by the National Park Service:

1. Mack, Robert C. and Grimmer, Anne E. *Preservation Brief No. 1: Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings*. National Park Service. 2000. 30 July 2009.
<<http://www.nps.gov/history/hps/tps/briefs/brief01.htm>>.
 2. Grimmer, Anne E. *Preservation Brief No. 6: Dangers of Abrasive Cleaning to Historic Buildings*. National Park Service. 1979. 28 July 2009.
<<http://www.nps.gov/history/hps/tps/briefs/brief06.htm>>.
 3. Weaver, Martin E. *Preservation Brief No. 38: Removing Graffiti from Historic Masonry*. National Park Service. 1995. 28 July 2009.
<<http://www.nps.gov/history/hps/tps/briefs/brief38.htm>>
- C. See, Historic Preservation Technical Procedures Standards. General Services Administration. 30 July 2009.
<http://w3.gsa.gov/_852565c500543eb4.nsf?OpenDatabase>.
- D. *Cleaning Techniques in Conservation Practice*. Edited by Kyle C Normandin and Deborah Slaton, Consultant Norman R Weiss, Managing Editor Jill Pearce. A special issue of the Journal of Architectural Conservation. Vol. 11 No. 3. November 2005.
- E. *Conservation of Historic Stone Buildings and Monuments: Report of the Committee on Conservation of Historic Stone Buildings and Monuments*. National Material Advisory Board, Commission on Engineering and Technical Systems, National Research Council. Washington, D.C.: National Academy Press, 1982.
- F. Grimmer, Anne E. *Keeping it Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings*. Darby, Pennsylvania: Diane Publishing Co., 1992.
- G. Staehli Alfred M. "Appropriate Water Pressures for Masonry Cleaning: What Do the Numbers Mean?" *APT Bulletin*, Vol. 18, No. 4 (1986), pp. 10-17. Published by: Association for Preservation Technology International (APT).
- H. Weaver, Martin E. *Conserving Buildings: A Manual of Techniques and Materials*. Revised edition. New York: John Wiley & Sons and the Preservation Press, 1997.
- I. Weiss, Norman R. *Exterior Cleaning of Historic Masonry Buildings*. Washington, D.C.: National Park Service, February 1977.

1.06 SUBMITTALS

The Contractor shall submit to the Architect:

- A. A detailed schedule of the areas to be cleaned, including an assessment of the problem surfaces, and proposed masonry procedures, application methods, dwell times, etc., for approval once cleaning test panels are completed and approved.
- B. The manufacturer's product literature for all proprietary cleaning products. Product literature shall include specification data, Material Safety Data Sheets, and instructions for storage, handling, and use.

1.07 QUALITY ASSURANCE

- A. The Contractor performing the work described in this Section shall have a minimum of seven (7) years experience in masonry cleaning and restoration and shall have successfully completed at least three projects of similar scope within the previous five years. He/she shall demonstrate a working knowledge of *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*.

1.08 MOCK-UPS

- A. The Contractor, at locations designated by the Architect, shall prepare test panels not to exceed 100 square feet per sample demonstrating the cleaning product on inconspicuous areas, preferably conducted by the operator undertaking the final work.
 - 1. Water Soak Cleaning – Approximately 50 square feet.
 - 2. Chemical Cleaners – Approximately 25 square feet for each specified product.
- B. More than one test panel may be required for approval. If necessary the Contractor shall prepare at least four (4) test panels of each type without further compensation. Approved test panels shall become part of the work and shall serve as the quality standard for all similar work.

1.09 DELIVERY, STORAGE, AND HANDLING (as applied to products and materials)

The Contractor shall:

- A. Deliver restoration cleaning and testing materials and proprietary products to the project site in manufacturer's or distributor's packaging, undamaged, complete with application instructions and Material Safety Data Sheets
- B. Store and transport cleaning agents, chemicals, and solvents within the temperature range recommended by the manufacturer and away from direct sunlight. Handle all materials according to manufacturer's instructions.
- C. Collect and dispose of waste material, packaging, debris, and effluent associated with the masonry cleaning work in accordance with local, state, and federal environmental regulations.

1.10 PROJECT / SITE CONDITIONS

- A. The work of this Section shall be executed only when the air and surface temperatures are 40 degrees Fahrenheit and rising or less than 90 degrees F and falling. Minimum temperature for masonry cleaning shall be 50 degrees F and above for at least two hours after completion and above freezing for at least 24 hours after completion. Work shall not commence when rain, snow, or below-freezing temperatures are expected within the next 24 hours. All surfaces shall be free of standing water, frost, and ice.
- B. The Contractor is responsible for protecting existing adjacent materials during the execution of the work and shall provide all necessary protection and follow all necessary work procedures to avoid damage to existing material assemblies not a part of the work of this Section. At a minimum, the Contractor shall:
 - 1. Protect woodwork, glass, and metal adjacent to masonry areas to be cleaned from overspray and possible chemical or water damage from cleaning operations. Cover all window openings with waterproof plastic to prevent leakage to the building interior.
 - 2. Protect surrounding lawns and vegetation from runoff during cleaning operations.
 - 3. Access work areas from the exterior only. Under no circumstances are hoses to be run or equipment transported through the building during cleaning operations.
- C. The Contractor shall erect waterproof enclosures around areas where cleaning operations are in progress to protect nearby property and passers-by from overspray of cleaning chemicals or rinse water.
- D. The Contractor shall coordinate masonry cleaning operations with the other trades involved in exterior and interior restoration work, including but not limited to masonry restoration, sealing, and painting. Masonry cleaning is to be completed prior to restoration of windows, doors, and metalwork, and prior to any exterior painting in the affected areas.
- E. All Contractor personnel performing masonry cleaning operations shall be provided with gloves, respirators, protective clothing and any other personal protective equipment as recommended by the manufacturer of the masonry cleaning products and required by local, state, and federal regulations.
- F. The Contractor shall complete installation of temporary sealants at window and door perimeters prior to starting cleaning operations where required to prevent leakage to interior.

PART 2 - PRODUCTS

2.01 MASONRY CLEANING OF ATMOSPHERIC SOILING

- A. Investigations and Method selection:
 - 1. Identification of material types, surface and substrate conditions, previous treatments, and the nature, cause and pattern of the soiling type for each area shall be determined. Testing may require additional technical expertise from a materials scientist, architectural conservator, microbiologist, and/or other technical expert. The Contractor shall choose the gentlest method possible to remove the soiling without damaging the substrate material.
 - 2. The Contractor shall conduct cleaning test patches, usually less than 6 inch by 6 inch, in unobtrusive locations on the masonry to be cleaned. The purpose of the test patch is to determine the gentlest, most effective method to remove soiling from the masonry. Several cleaning methods are generally tested side by side.
 - 3. The method of cleaning and the level of clean shall be approved by the Architect. The Contractor shall protect adjacent materials, installed non masonry materials, and openings.
- B. Cleaning methods: Cleaning shall be undertaken through the mildest, least abrasive method.
 - 1. The following methods are gentlest and should be considered first:
 - a. Water with soft brushes
 - b. Water with mild soap
 - c. Water with stronger soap
 - d. Water with stronger soap plus ammonia
 - e. Water with stronger soap plus vinegar
 - 2. Water washing: Washing the surface with low to medium jet pressure, 200-500 pounds per square inch (psi) at 4-6 gallons per minute (gpm) using a 45degree fan type nozzle, for water soluble dirt and chemical compounds. Optimal water pressure and wand distance are to be determined during preparation of cleaning test patches. Note that most commercial pressure washing systems operate at significantly higher pressures than those recommended. Use of a pressure regulator to reduce pressures may be needed.
 - 3. Nebulous Sprays: Application of intermittent mist spray under low pressure to dampen surface. Dirt is removed through differences in drying rates of the soiling and substrate. Swelling of the soiling generally loosens its attachment to the substrate. Optimal water pressure, time cycles, and duration of the cleaning technique are to be determined during preparation of cleaning test patches.
 - 4. Detergents: Formulations made with dilutions of cleansers, surfactants, and chelating agents in water. Neutral or non-ionic detergents or surfactants are added to water for use on hydrophobic stains.

5. Masonry Cleaners: Proprietary cleaning solutions containing detergents, acidic or alkaline compounds. If this type of product is proposed, great care must be exercised in product selection and preparation of test panels to identify potentially detrimental effects on the masonry. This type of product is not recommended for polished stones or extremely fragile or deteriorated masonry. The use of raw acids and/or alkalis for masonry cleaning is not permitted at any time.
- C. Water used for cleaning of historic masonry cleaning shall be potable and free of injurious amounts of oil, soluble salts, alkali, acids, and other impurities that might stain or otherwise damage masonry.
 - D. Equipment for masonry cleaning:
 1. Pipes and hoses used for water cleaning shall be plastic or other similar material that is not subject to corrosion, which can cause discoloration and staining of surfaces being cleaned.
 2. Natural bristle brushes shall be used for scrubbing. Metal bristle brushes are not to be used.
 3. Hoses, fittings, and equipment to be used for application of proprietary cleaning compounds shall be solvent, acid, or alkali-resistant as recommended by the manufacturer of the cleaning products.
 4. Buckets, trowels, and other tools to be used for mixing and application of poultices shall be solvent-resistant plastic. Wood scrapers and trowels are also permitted. No metal tools are to be used.
 - E. Water/rinsing method: Surfaces shall be rinsed with water after cleaning. Rinse water will be collected and disposed of in accordance with federal state, and local environmental standards. Rates of water pressure shall be no greater than 500 psi at 3-6 gpm with minimal saturation.

2.02 MASONRY CLEANING OF STAINS

- A. Investigations and method selection:
 1. Types of materials, surface and substrate conditions, previous treatments, and the nature, cause and pattern of the stain, corrosion, or deposits for each area shall be determined. Testing may require additional technical expertise from a materials scientist, architectural conservator, microbiologist, and/or other technical expert. The Contractor shall choose the gentlest method possible to remove the stain without damaging the substrate material.
 2. The Contractor shall conduct cleaning test patches, usually less than 6 inch by 6 inches, in unobtrusive locations on the masonry to be cleaned. The purpose of the test patch is to determine the most effective, gentlest method to remove stains from the concrete. Several cleaning methods are generally tested side by side.
 3. The method of cleaning and the level of clean shall be approved by the Architect.

B. Cleaning Methods:

1. Poultices (see Section 04510.03)
2. Cleaning solutions to be used in a poultice mixture may include chelating agents such as EDTA (ethylenediaminetetraacetic acid), ammonium citrate, sodium citrate, citric acid, and oxalic acid. Seek additional professional advice if chelating agents are to be used in a poultice.
3. Organic solvents or inorganic chemicals in water, either ready-made or site mixed, can be used to remove some stains. Care must be exercised so that the stain isn't pushed further into the masonry. Also, many cleaners can be toxic to workers and damage adjoining building materials, always follow the manufacturer's recommendations and safety standards.

C. Equipment for Application (see Atmospheric Soiling, Sec 2.01 D above)

D. Water/rinsing Method (see Atmospheric Soiling, , Sec 2.01 E above)

2.03 MASONRY CLEANING OF GRAFFITI.

A. Investigations and Method Selection:

1. Identification of materials types, surface and substrate conditions, previous treatments, and the materials used to create the graffiti for each area shall be determined. Testing may require additional technical expertise from a materials scientist, architectural conservator, microbiologist, and/or other technical expert. The Contractor shall choose the gentlest method possible to remove the graffiti without damaging the substrate material.
2. The Contractor shall conduct cleaning test patches in unobtrusive locations on the concrete to be cleaned. The purpose of the test patch is to determine the gentlest, most effective method to remove stains from the masonry. Several cleaning methods are preferably tested side by side.
3. Incised graffiti cannot be addressed by cleaning, and is therefore not covered under this section. If the damage is deep, removal may be addressed in Sections 04500.02 and 04500.03.
4. Staining and graffiti should be addressed after atmospheric soiling and biogrowth are removed.
5. Graffiti is most easily removed when it has been freshly applied. Therefore, timely removal of graffiti is important.

B. Cleaning Methods:

1. Water and Detergent: Washing the surface with water at low to medium jet pressure, 500 psi or less at 3-6 gpm. Neutral or non-ionic detergents may be introduced. Note that most commercial pressure washing systems operate a significantly higher pressures than those recommended. Use of a pressure regulator to reduce pressures may be needed. Use the lowest possible pressure to achieve the desired results.
2. Poultices: A paste or slurry made with absorbent material or powder-inert clay, such as kaolin or sepiolite, diatomaceous earth (fuller's earth); or Cellulose products such as pulp cellulose, shredded paper that is mixed with a cleaning solution (a liquid reagent such as water, organic solvent, or paint stripper among others).
3. Organic Solvents and Paint Removers: Proprietary graffiti-removal products and/or commercial paint strippers containing organic solvents, sol gels, gel or paste removers, or paper or cloth-backed removers. Do not use "off-the-shelf" aerosol graffiti removers as these can cause additional staining and redistribution of pigments to clean areas.

C. Equipment for Application: See Atmospheric Soiling above

D. Water/rinsing Method: See Atmospheric Soiling above

2.04 CLEANING BIOGROWTH AND BIRD DROPPINGS

A. Investigations and Method selection: Material types, surface and substrate conditions and the nature, cause and pattern of biomaterials for each area shall be determined. The cleaning method shall be approved by the Architect.

B. Cleaning Methods:

1. Water Washing: Cold water applied at 200-500 psi pressure. A commercially available biocide, generally containing a quaternary ammonium treatment, may be introduced for treatment of algae, fungi, molds, and mildew. Use lowest possible pressure to achieve desired results.
2. Acidic Cleaners: Formulations of acids, surfactants, and chelating agents.
3. Poultices: See Section 04510.03.

C. Equipment for Application: See Atmospheric Soiling, Sec 2.01 D above

D. Water/rinsing method: See Atmospheric Soiling, Sec. 2.01 E above

2.05 STONE PROPERTIES AFFECTING CLEANING

- A. **Calcitic Stone (Limestone, Marble and some Sandstones):** Marble, limestone and some sandstones are acid sensitive. Acids can cause etching and dissolution of the stones and should not be used for their cleaning.
- B. **Silicate Stone (most types of Sandstone):** There are many kinds of sandstone, each of which has a different geological composition. For example, sandstones that contain water-soluble minerals can be eroded by water cleaning. Some sandstone can be cleaned with acids; others are sensitive to acid and can be severely etched or dissolved by an acid cleaner.
- C. **Granite:** This extremely hard, dense stone is generally not adversely affected by chemical cleaning. However, the use of strongly acidic cleaners may cause selective etching and/or bleaching of the constituent minerals, resulting in a change in appearance, particularly for polished stones. Additionally, some granites and gneisses contain impurities that may be eroded or chemically converted by inappropriately strong or improperly applied acidic cleaners, resulting in a weakened surface that may deteriorate at an accelerated rate in the future. Where possible, petrographic analysis should be sought when planning a large granite masonry cleaning project if chemical cleaning is proposed.
- D. **Schist and Gneiss:** These are metamorphic rocks derived from clays and silts (schist) or igneous rocks (gneiss) and containing a proportion of platy minerals such as mica and hornblende, often combined with quartz and feldspar. Schists are generally highly micaceous and are distinguished by their foliated or platy texture and easily split along their micaceous layers. Gneisses are formed under higher temperatures, forming distinct mineral bands. They also contain a small proportion of micaceous minerals. The strength and chemical resistance of schists and gneisses varies widely and is best assessed by preparation of cleaning test patches.
- E. **Shale and Slate:** Shale is a fine-grained sedimentary rock composed primarily of clay and silt particles derived from quartz and feldspar minerals. Shale is a very porous rock that will absorb most liquids. Care must be taken with Shale because it may contain water-soluble minerals that can be eroded by water cleaning. Slate is a fine-grained layered metamorphic rock derived from shale under low to moderate heat and pressure. Slate is relatively common as a finish material for floors, walls, and roofs because of its low permeability. As it is composed primarily of quartz and feldspar, slate is relatively unaffected by mild acids.

PART 3 - EXECUTION

3.01 GENERAL

- A. The initial cleaning test patches shall be undertaken by Contractor and reviewed by the Architect to determine the mildest cleaning method to be used once cleaning test patches are approved. Cleaning mock-ups will be prepared by the Contractor, and reviewed by the Architect.

- B. Contractor shall submit testing schedule and a cleaning schedule, including the methods and materials to be used.
- C. The Contractor shall protect all adjacent materials from spray and chemicals.
- D. The runoff from the cleaning process will be collected in plywood troughs lined with polyethylene sheeting. Polluted liquid gathered shall be pumped into tanker trucks or drums for properly controlled disposal. Acidic runoff shall be neutralized with lime or soda ash prior to release.
- E. Masonry cleaning shall be completed prior to masonry repointing and repairs. The Contractor shall remove and store light fixtures, downspouts, and other appurtenances to ensure full access to wall surfaces, unless otherwise noted by the Architect. Anchor holes and penetrations from appurtenances must be temporarily filled with removable sealant or protected with cover plates.
- F. The Contractor shall remove invasive plants and plant debris from the structure prior to cleaning. With the approval of the Architect, invasive vines shall be cut close to the ground and allowed to wither and dry. This method allows the vines to contract and withdraw from the masonry. The process may take up to two weeks. The dry vines shall be carefully removed and the façade surface cleaned with a natural bristle brush prior to other treatments.
- G. After removing invasive species, the Contractor shall protect desirable plants surrounding the building from chemicals and cleaning efforts. This may include tying back plants away from the building. Covering plants may be needed as well. Hard pruning may be appropriate with approval of the Architect.

3.02 MASONRY CLEANING

- A. Surface Preparation for Cleaning
 - 1. Examine the surfaces to be cleaned prior to commencing cleaning operations. Large cracks (one-eighth inch or larger) and open joints discovered shall be temporarily filled with removable sealant to prevent penetration of cleaning solutions into the core of the wall.
 - 2. Window and door openings shall be protected from leakage and damage from cleaning solutions by plastic sheeting or another waterproof membrane. Open joints around window frames and door frames shall be filled with temporary sealant to prevent leakage.
- B. Nebulous Spray Water Mist Cleaning
 - 1. A water misting apparatus will be designed to suit the size of the masonry to be cleaned. Generally, the nebulous spray misting system consists of PVC pipe and fittings, flexible mist-type spray heads spaced evenly based on cleaning needs, and a timed shutoff valve for on/off cycling. The nebulous spray misting system is suspended beneath the overhanging surfaces to be cleaned. Conditions that can be varied and must be controlled include
 - a. available water pressure delivered to the system,

- b. volume of water delivered from each sprayer,
 - c. nozzle shape,
 - d. droplet size,
 - e. distance from surface, and
 - f. duration of on/off cycles.
2. Cleaning conditions with the nebulous spray system shall be optimized prior to cleaning the masonry surface. Intervals for wet dry cycles vary widely based on the cleaning action desired. Cycles can be as short as three seconds on and 40 seconds off, to as long as four hours on and four hours off for a period of 24 hours. It is generally recommended to start from the top of the masonry structure and work downward.
 3. During misting, the nozzles can be adjusted to apply mist on the most concentrated areas and crevices. Natural bristle brushes can be used to aid in the removal of heavily soiled areas or cleaning of high relief decoration.
 4. Final washing of each section shall consist of a low pressure wash, not to exceed 300 psi. Rinse surfaces from top to bottom using a 45 degree fan-tip nozzle. Maintain a minimum distance of 18 inches between the nozzle tip and the masonry surface. Use the lowest possible pressure to achieve desired results.

C. Chemical Cleaning

1. Masonry surfaces shall be saturated with water prior to application of chemical cleaning products to prevent undesirable absorption of cleaning chemicals.
2. Cleaning of masonry walls shall proceed from the bottom of the wall upward to minimize streaking.
3. Apply the masonry cleaning product in accordance with manufacturer's instructions and approved cleaning procedure submittal. The Contractor shall use fiber brushes, rollers or very low-pressure spray (not to exceed 100 psi) for application. The Contractor shall not use high-pressure spray equipment to apply cleaning product.
4. After completion of the appropriate dwell time, loosened soiling shall be removed using a low-pressure water rinse. Do not allow the cleaning products to dry on masonry surfaces. Rinse surfaces from top to bottom using a 45 degree fan-tip nozzle with a nozzle pressure not to exceed 500 psi and a flow of approximately four gpm. A minimum distance of 18 inches between the nozzle tip and the masonry surface shall be maintained.
5. After cleaning is completed, the Contractor shall remove protective coverings from adjacent surfaces and repair any damage or staining caused by the cleaning operation to adjacent surfaces.

D. Removal of Metallic Stains: See Section 04510.03, Poulticing and Salt Removal

E. Removal of Salts: See Section 04510.03, Poulticing and Salt Removal

F. Cleaning Graffiti

1. Apply the specified paint stripper using a brush, roller or low pressure spray apparatus equipped with a nozzle 0.019 inch or larger. Spray equipment must be equipped with chemical resistant packing and hoses. Apply to a minimum thickness of 10 mils.
2. Allow the stripper to remain on the surface in accordance with the dwell time determined during preparation of the approved test panel. Dwell time will increase as temperatures decrease.
3. Following dwell time the Contractor shall remove lifted layers using a squeegee, plastic scraper, or wet vacuum device as required. Collect paint and stripper residue, and dispose in accordance with local, state and federal regulations.
4. Thoroughly rinse surface with clean water. Reapply stripper as required to remove all existing paint layers.

G. Removal of Algal Growth, Moss, and Bird Droppings (Biological Staining)

1. Do not remove living mosses, lichens, and higher order plants without first killing them with a biocide, since roots and other attachments may penetrate deeply into the masonry. Allow time for the plant to detach before attempting removal. The Contractor may apply a biocidal product such as a quaternary ammonium product to colonies of moss, or other biological contaminants. After at least 24 hours, the Contractor may remove colonies of moss, loose growth, and accumulations of bird droppings from masonry surfaces to be cleaned using wooden scrapers.
2. The Contractor shall apply selected cleaning agent in accordance with manufacturer's instructions and approved test panel. Allow product to dwell on soiled surfaces to achieve optimal cleaning.
3. Following required dwell time, agitate with a soft bristle brush to lift and remove embedded growth. The Contractor shall flush surfaces with low to medium-high pressure (not to exceed 500 psi) water rinse as required to remove staining. Repeat application as required to remove stains.
4. Spot clean for heavily soiled areas (biological growth):
 - a. Spot cleaning shall be performed only after general cleaning has been completed for approximately two weeks.
 - b. Thoroughly wet surfaces to be treated with spot cleaner. Apply the product using a synthetic brush, roller or low-pressure spray and allow it to dwell on the surface. Dwell time to be in accordance with the approved test panel.
 - c. After dwell time has elapsed, thoroughly rinse the surface with clean water at moderate pressure (500 psi or less), working from the bottom up.

- d. Apply neutralizing rinse (if required) and allow to dwell on the cleaned surface three to five minutes. Following the required dwell time, rinse the surface again with clean water at moderate pressure(500 psi or less), working from the bottom up.

3.03 FINAL REPORT

The Contractor shall:

- A. Provide a final report of completed work, including all approved submittals and photographs of the areas cleaned that were taken before, during, and after the work.
- B. Provide a written summary of the project and results upon final inspection and approval. The summary shall include a discussion of steps taken or new findings not specified in the initial documentation.

END OF SECTION

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13. SUPPLEMENTARY NOTES					
14. ABSTRACT Federal preservation laws require federal agencies to identify, protect, and maintain their historic buildings and structures. The German POW Stonework Historic District, which is eligible for the National Register of Historic Places, recognizes and protects the stonework created by German prisoners of war (POWs) from 1942 through 1946. All structures, especially historic ones, require regular, planned, and appropriate maintenance and repair. After identifying issues with the condition of the historic stonework, architects at the U.S. Army Engineer Research and Development Center--Construction Engineering Research Laboratory (ERDC-CERL) requested technical assistance from the National Center for Preservation Technology and Training (NCPTT) on behalf of U.S. Army Garrison Fort Leonard Wood (FLW). Two experts from NCPTT made a site visit to inspect the stonework, taking samples and photos. Their technical report, made part of this ERDC-CERL contract report, provides recommendations for preservation or restoration of the stonework, following the <i>Secretary of Interior's Standards for the Treatment of Historic Properties</i> . The NCPTT report also summarizes various threats to the condition of both stone and mortar. FLW's Directorate of Public Works will use the report's recommendations to correct existing issues and to maintain the historic stonework.					
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